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The Relative Benefits of Green Versus Lean Office Space: Three Field Experiments

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Principles of lean office management increasingly call for space to be stripped of extraneous decorations so that it can flexibly accommodate changing numbers of people and different office functions within the same area. Yet this practice is at odds with evidence that office workers' quality of life can be enriched by office landscaping that involves the use of plants that have no formal work-related function. To examine the impact of these competing approaches, 3 field experiments were conducted in large commercial offices in The Netherlands and the U.K. These examined the impact of lean and "green" offices on subjective perceptions of air quality, concentration, and workplace satisfaction as well as objective measures of productivity. Two studies were longitudinal, examining effects of interventions over subsequent weeks and months. In all 3 experiments enhanced outcomes were observed when offices were enriched by plants. Implications for theory and practice are discussed.

Keywords: space, office, plants, well-being, productivity

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Shortly after his British general election victory in 2010, Prime Minister (PM) David Cameron singled out the cost of flowers and pot plants in Whitehall's offices as clear evidence of the need to eliminate waste in the public sector (Saner, 2012). His Communities Secretary, Eric Pickles, quickly followed suit and cancelled his department's floristry bill and berated the Audit Commission for spending £40,000 on plants in its working environments.

Yet it appears that many of the PM's cabinet colleagues were not on message. It was revealed that four major government departments — including the Foreign Office and Treasury (where Chancellor George Osborne is responsible for the Government's austerity program)—spent £34,297.54 between them on plants and flowers in the year after the Conservative election victory (Hansard, 2011). Luciana Berger Member of Parliament "denounced the spending" (Morris, 2011, p. 11). David Laws, Treasury Secretary, subsequently declared that his department's spending on plants had been cut to zero (Crampton, 2011).

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Less is More: The Lean Office

Cameron's policy—which was widely applauded in some circles—is clearly informed by a belief that money spent on office plants is money wasted (Dravigne, Waliczek, Lineberger, & Zajicek, 2008). This is a sentiment that is widely shared within the business literature, where it is argued that clean, obstruction-free work-surfaces are the most economical route to business health and productivity (e.g., Haberkorn, 2005; Tapping & Dunn, 2006). This lean philosophy has a long history. Indeed, the idea that productive work requires a workspace clear of any interference was first formally implemented by Josiah Wedgwood in the 18th century (Dolan, 2004) and centuries later inspired Frederick Taylor (1911) to apply his principles of scientific management to the organization of office space (e.g., Crompton & Jones, 1984; Haslam & Knight, 2010, for a review). During the mid-20th century, these manufacturing methods were also applied to white-collar work (Haberkorn, 2005; Hyer & Wemmerlov, 2002) and it is from this approach that the term the "lean office" emerged as a discrete concept in the 1990s (e.g., Hirano, 1996). Reflecting this, it is common for managers to insist that workspaces should be clear of plants, pictures, souvenirs, food, and anything not directly required for the job at hand in attempt to streamline business operations and maximize productivity (Haslam & Knight, 2006; Skinner, 2005).

More generally, it has been observed there is a trend for offices to move toward minimal decoration for two major reasons (Markovitz, 2012). First and most importantly, this reflects the widespread influence of a *lean* corporate philosophy. As the first sentence of the *Lean for Dummies* guide puts it: "The principles and practices of lean organizations are recognized the world over as the most

powerful and effective way to build and sustain continuously improving buildings and institutions" (Sayer & Williams, 2006, p. 1). As Mann (2010) explains "Lean . . . has proved to be an unbeatable way to organize productive operations" (p. 15). Second, the lean concept is seen to have particular appeal in a time of general economic recession because it fits with an emphasis on austerity and cost-cutting (Saner, 2012). In a world where people are losing their jobs, investment in plants and other "nonessential" items appears frivolous.

Yet, perhaps because the idea that lean space is more productive is so intuitively appealing, there is almost no quantitative evaluation or controlled experimentation to support these ideas (e.g., see Haberkorn, 2005; Worthington, 2006). Lean evidence is drawn more or less exclusively from selective case studies (e.g., Honeywell, NY Government Offices; see Harris & Harris, 2006; Markovitz, 2012). But case studies of lean success can be countered with equally dramatic instances of failure (e.g., HM Customs and Revenue; Haslam & Knight, 2006). As far as we know, there is only one experimental study of the effects of office design (Knight & Haslam, 2010b). This research showed that people who work in an environment enriched by office plants and artwork were more productive than their counterparts assigned to work in a lean space. Meanwhile, recorded levels of well-being—as measured by sick office syndrome, feelings of comfort and levels of job satisfaction—were significantly higher in an enriched space. Thus, in a direct comparison of enriched spaces and lean office space, the lean office was clearly inferior on all dimensions.

The Green Office: Improved Performance

Despite the enormous influence of lean philosophy on office space management (George, 2003), its conclusions have been challenged within both design and science. Perhaps the clearest suggestion that office space might benefit from enrichment emerges from the practice and literature surrounding the introduction of plants to office spaces. Such work was initially led by the German Bürolandschaft movement (office landscaping), pioneered by Eberhard and Wolfgang Schnelle, which sought to enrich office space with plants in the 1950s and used indoor plants and partitions to provide environmental enrichment and privacy (Duffy & Hutton, 1998; Vischer, 2005). The intention was not only to provide a more efficient working environment: Bürolandschaft assumed that plants would make an environment more collaborative and humane (Sundstrom & Sundstrom, 1986).

Studies of living plants in the workplace have indeed suggested that they can have a range of beneficial influences. In particular, a number of researchers have investigated the effects of indoor plants on outcomes relevant to the effectiveness and well-being of office workers. Those outcomes include psycho-physiological stress responses, task performance, emotional states, and room assessments (Adachi, Rohde, & Kendle, 2000; Chang & Chen, 2005; Coleman & Mattson, 1995; Kim & Mattson, 2002; Larsen, Adams, Deal, Kweon, & Tyler, 1998; Liu, Kim, & Mattson, 2003; Lohr, Pearson-Mims, & Goodwin, 1996; Shibata & Suzuki, 2001, 2002, 2004). In addition, some studies have investigated the effects of indoor plants on health and discomfort symptoms related to the sick building syndrome (Fjeld, 2000; Fjeld et al., 1999; Fjeld, Veiersted, Sandvik, Riise, & Levy, 1998).

Outside the workplace, there is evidence that exposure to plants and natural settings (as opposed to urban settings) can improve positive mood and reduce negative mood (Hartig, Evans, Jamner, Davis, & Garling, 2003; Ulrich, 1979; Ulrich et al., 1991). Findings also indicate that physiological stress, or arousal (as measured by heart rate, blood pressure, and/or skin conductance) is often lower after exposure to plants and nature as compared with urban settings (Hartig et al., 2003; Laumann, Gärling, & Stormark, 2003; Ulrich & Simons, 1986; Ulrich et al., 1991). Furthermore, increases in well-being have been shown to coincide with less mental distress among people living in urban areas interspersed with green spaces (White, Alcock, Wheeler, & Depledge, 2013). In addition, exposure to nature has been shown to have the capacity to improve attention (Berman, Jonides, & Kaplan, 2008; Berto, 2005; Cimprich, 1993; Cimprich & Ronis, 2003; Hartig et al., 2003; Ottosson & Grahn, 2005; Tennessen & Cimprich, 1995).

An obvious question is why plants and green spaces might have these beneficial psychosocial benefits. Currently, there are three classes of explanations for such findings. According to the first, plants, as living organisms, exert a beneficial influence on the climate of the working and living environment. In particular, plants are thought to be healthy because they improve air quality. In this regard, when introduced in sufficient quantity, indoor potted plants have been shown to remove most types of air-borne pollutants arising from either outdoor or indoor sources. This has been studied within laboratories (Orwell, Wood, Tarran, Torpy, & Burchett, 2004; Tarran, Orwell, Burchett, Wood, & Torpy, 2002; Wood, Orwell, Tarran, Torpy, & Burchett, 2002), as well as in naturally ventilated and air-conditioned office spaces (Tarran, Torpy, & Burchett, 2007; Wood et al., 2006). Air pollutants, even at imperceptible levels, can cause "building-related illness" and symptoms of headache, sore eyes, nose, and throat, or nausea (Carrer et al., 1999; Mølhave & Krzyzanowski, 2003). Where indoor plants have been installed, staff well-being is improved with reduced sick-leave absence (Bergs, 2002; Fjeld, 2000). In addition, plants can refresh the air by absorbing carbon dioxide (CO_2). The importance of this is suggested by studies which show that student performance declines with increasing CO_2 (Shaughnessy, Haverinen-Shaughnessy, Nevalainen, & Moschandreas, 2006), as does workplace productivity (Seppänen, Fisk, & Lei, 2006). Instructive in this regard is a study by Tarran, Torpy, and Burchett (2007) which showed that in the presence of plants, CO_2 levels were reduced by about 10% in air-conditioned buildings, and by about 25% in naturally ventilated buildings. However, as well as objective changes in air quality, the presence of plants might also result in a *perceived* change in air quality. This question was investigated by Khan, Younis, Riaz and Abbas (2005) in an academic setting. They found that students who worked in an environment that had been enriched with plants reported that air quality had improved. Such data thus suggest that enriching the workplace with plants should have a positive effect on the (subjective) air quality within the working environment.

The second explanation of plants' beneficial effects centers on the evolutionary explanation that a green, planted environment reflects the natural world and thereby supports human physiology (Appleton, 1975; Balling & Falk, 1982; Kaplan, Kaplan, & Brown, 1989; Orians, 1980; Orians & Heerwagen, 1992; Ulrich, 1983, 1986). Proponents of *attention restoration theory* (ART; Kaplan, 1995) argue that natural environments restore people's capacity for

directed attention, whereas built environments tend to deplete this capacity. The idea behind this theory is that the prolonged focus on a specific stimulus or task results in "directed attention fatigue." According to ART, natural environments exert less demand on directed attention and encourage more effortless brain functions, thereby allowing the capacity for attention to be restored. Thus, after an interaction with natural environments, one is able to perform better on tasks that rely on directed-attention abilities. According to this view, plants in the workplace should enhance employees' directed-attention capacity and therefore enhance their concentration and productivity levels.

The third class of explanations moves away from physiological responses and looks more closely at the relational and managerial consequences of enrichment. The basic idea here is that enrichment of the workspace (with plants or by other means) signals that attempts are being made to enhance staff well-being and "environmental comfort" (Vischer, 2005, p. 102). Enrichment thus communicates managerial care and attention (a sense that "our managers are on our side"), which may in turn lead to increased attention and work engagement among employees (e.g., as argued by Haslam, 2004; see also Katz & Kahn, 1966; Lewin, 1956). It also follows that if people are physically, cognitively and emotionally involved in their work there is a reduced risk of disengagement (Kahn, 1990). This in turn is likely to translate into higher levels of work satisfaction, productivity, and well-being (Ottosson & Grahn, 2005; Parker, 1992; Tennessen & Cimprich, 1995).

Enrichment can be achieved in multiple ways, including via indoor plants. Speaking to this possibility, a study by Dravigne, Waliczek, Lineberger, and Zajicek (2008) showed that individuals who worked in offices with plants reported that they felt better about their job and the work they performed. Enriched offices are also psychologically advantageous because they communicate and help build a sense of belonging and shared identity (Elsbach, 2003; Handy, 1990; Haslam & Knight, 2006; Myerson, 2007; Thompson, 2000; Vischer, 2005; Zelinsky, 2006). In short, enriching the environment with plants should signal managerial care and hence result in increased engagement, attention and environmental satisfaction. More broadly, this should also result in perceived improvement to psychological well-being and productivity in the workspace.

The Present Research

Although previous work suggests that "greening" an office can improve productivity and well-being, extant studies have clear limitations (see also Bringslimark, Hartig, & Patil, 2007). In particular, the offices in which research has been conducted were constructed specifically for the purpose of the research and thus were rather artificial (notable exceptions being field studies by Fjeld, 2000; Fjeld et al., 1999, 1998; Shoemaker, Randall, Relf, & Geller, 1992). Moreover, they involved a single individual working in isolation in an unfamiliar environment without reference to her or his standard work patterns and without social interaction. Consequently, although the studies were designed to capture the essence of office work, their ecological validity was limited. Further, some research confounded plants with other decorations, making it difficult to extrapolate the benefits—or otherwise—of a green office (e.g., Knight & Haslam, 2010b). Finally, previous studies were short-term, and we cannot establish whether the reported effects would have continued to produce beneficial effects for any length of time.

A more persuasive test of the relative merits of lean and green offices would therefore involve collecting data in more realistic field contexts, and with plants only. This was the primary goal of the present research. More specifically, it involved conducting three experiments to examine the effects of introducing living plants within a functioning office.

In all the experiments, office design was manipulated across two conditions.[1] In a *lean* condition, minimalist office space was intended to focus employees' attention solely on the work at hand. In the *green* condition, employees fulfilled the same work in an office that incorporated plants. Study 1 was a longitudinal field experiment that examined the short-term effects of office design on workers' environmental satisfaction (perceived air quality, perceived concentration, workplace satisfaction and perceived productivity). Study 2 examined the long-term effects of office design on the same dependent variables, except focusing on objective rather than subjective productivity levels. Study 3 examined the effects of office design on levels of productivity.

Study 1

Our first experiment was conducted at the offices of an international consultancy business in central London. The floor where the study took place had an open plan office design and employees were mainly involved with the implementation and management of large projects which also involved client meetings outside the office. As a result, there were more employees nominally based in the building than there were places at which they could work. The desks were taken on a first-come,-first-served—or hot-desking—basis (Barnatt, 1995; Millward, Haslam, & Postmes, 2007). The employees themselves were highly paid consultants. The study took place in one space, which was deliberately designed to be lean. Different areas within this space were assigned to one of two conditions. In one, the space remained lean; in the other the office was landscaped with plants. The main goal of the study was to examine whether this enrichment of office space had any impact on employees' well-being and productivity.

Method

Design. A 2 × 2 mixed design was employed in the study. *Office design* was manipulated as a between-subjects variable (lean, green). Both office designs were located on the same floor in open plan space and were separated from each other by architectural borders (e.g., cabinets and meeting rooms). In the lean space participants had no plants in direct sight of their workstation; in the green space plants were introduced into the office such that

[1] In Study 1 and Study 2, the intention was to make a comparison between three conditions: lean versus green versus empowered (as in Knight & Haslam, 2010b). In the empowered condition the procedure was the same as in the green condition with the exception that employees had say in the design of their office space (in comparison with the green condition were a designer developed the design). Because no significant differences were found between the green and the empowered condition (and empowerment had no significant additional value to the plants) both conditions were combined into one condition.

each employee had at least two in direct view. *Study phase* was a within-subjects variable, with measures administered both before the introduction of the plants (T1) and 3 weeks after their introduction (T2).[2]

Participants and procedure. The study was conducted on one floor of a large office building in central London. The floor was approximately 4875 m^2. All employees on the floor were invited via email to take part in the longitudinal study ($N = 250$). The study was presented as an investigation into employees' preferences for different kinds of office designs. One hundred and 66 employees (66% response rate) participated in the first measurement at T1. Eight weeks later—in the green office—an interior designer installed an array of green, large-leafed plants (average height 90 cm) around the workfloor. There was an average of three plants per five desks (at least two plants in direct sight of each desk). In the lean office no changes to the working environment were made. At T2, 3 weeks after the plants were installed, all employees received a follow-up e-mail inviting them to complete a second questionnaire. One-hundred and 48 employees completed this, representing a 59% response rate. In order to match questionnaires to the right person, participants were asked to generate a unique code at the beginning of their responses based on their mother's maiden name and their date of birth.

Allocation of space and participants to condition. At the start of the study two spaces on the floor were identified which were separated by architectural borders (e.g., cabinets and meeting rooms). The two spaces were randomly assigned to an office design (*lean* or *green*). Consequently, the space in which employees were working at the start of the study (i.e., the completion of the first questionnaire) defined the condition of which they were a part. Due to the use of hot-desking in the office, employees could in principle work wherever they liked on the floor. However, in practice, most employees tended to work in the same area every day and were therefore working in one type of office design (either *lean* or *green*) throughout the study. To verify where they were working, each wave of questionnaires included a map of the workfloor. Participants indicated (a) their main working area(s), and (b) the area(s) in which they had been working on each day of the previous week. Participants who indicated that their main working area was outside the office (42 at T1 and 51 at T2) were excluded from the sample (remaining *N*s: T1 = 124, T2 = 97). In addition, five participants who indicated that they had worked in both types of office designs could not be assigned to a specific condition and were also excluded from the sample.

The final sample. After applying the exclusion criteria, the total sample consisted of 153 participants (see Table 1 for a division per condition). The participants in this sample completed either one (T1 or T2) or two waves (T1 and T2) of the study. After listwise deletion, the final sample consisted of 67 participants who participated in both waves of the study. The final sample included 39 men and 28 women ranging in age from 23 to 53 years ($M = 30.02$, $SD = 6.41$). Analyses revealed no differences (on any measure) between the full samples at each time point and the final sample was retained for analysis.

Table 1
Sample Sizes per Wave and Condition for Study 1

Condition	T1	T2	Total sample (completed either T1, T2 or both)	Final sample (after listwise deletion)
Lean	54	52	71	34
Green	70	45	82	33
Total	124	97	153	67

Measures. Participants completed a questionnaire that included eight questions assessing four key constructs. In each case participants responded using a 7-point scale ranging from 1 (*completely disagree*) to 7 (*completely agree*). *Workplace satisfaction* was measured with four items ($\alpha_{T1} = .74$; $\alpha_{T2} = .75$; e.g., "I feel at home in the office," after Knight & Haslam, 2010b). *Concentration* was measured with one item (i.e., "In the office I am able to concentrate well," after Knight & Haslam, 2010b), as was *air quality* (i.e., "The office has poor air quality;" reverse-coded, after Knight & Haslam, 2010b). *Subjective productivity* was measured with two items ($\alpha_{T1} = .76$; $\alpha_{T2} = .75$; e.g., "I am happy with my performance lately," after Knight & Haslam, 2010b). In addition, demographic statistics were collected on *age*, *gender*, and number of *work years* for the company.

Results

Analytic strategy. Scores on all measures were subjected to a two-way analysis of variance (ANOVA) with office design (lean, green) as a between-subjects factor and study phase as a within-subject factor (T1, T2). This was followed up by simple effects analysis. Relevant means and statistics are presented in Table 2.

Demographics and premeasures. First, we tested whether there were any differences across the two office designs (*lean* vs. *green*) with regard to demographics of the participants. No significant differences were found on gender, $\chi^2(1) = 2.60$, $p = .11$ or on work years for the company, $t(65) = 1.56$, $p = .125$. However, a difference was found for age, $t(65) = 2.22$, $p = .031$, as participants in the lean condition where younger ($M = 28.13$, $SD = 5.31$) than participants in the green condition ($M = 31.31$, $SD = 5.92$). Upon further inspection, age was not significantly correlated with any of the dependent variables of interest (at T1 and T2; rs $< .12$, ps $> .30$) and therefore not included in the analysis of variance as a covariate.

Second, we tested if there were any differences across the two office designs in the premeasures. No significant differences were found on any of the dependent variables, ts$(65) < 1.65$, ps $> .10$.

Workplace satisfaction. Analysis of responses on this measure revealed a main effect for study phase, $F(1, 65) = 23.0$, $p < .001$, $\eta_p^2 = .26$, 90% CI [.12, .39]. On average, participants became more satisfied with their working environment over time ($M_{T1} = 3.77$, $M_{T2} = 4.39$). This effect was not qualified by office design, $F(1, 65) = 1.44$, $p = .234$.

Concentration. Analysis of participants' subjective concentration levels revealed a significant interaction between office design and study phase, $F(1, 65) = 8.59$, $p = .005$, $\eta_p^2 = .12$, 90% CI [.02, .24]. Simple effects showed that in the green condition participants perceived there to be an increase in their ability to

[2] A third measure was taken 2.5 months after the introduction of the plants (T3) but the sample size for a 2 × 3 design was too low ($N = 48$) to allow us to conduct the desired statistical analysis. Importantly, however, comparison between T2 and T3 on all dependent variables showed no significant differences between the two time-points.

Table 2
Study 1: Employees' Perceptions of Satisfaction, Concentration, Air Quality, and Productivity in Lean and Green Office Environments

		Phase				Effect		
		T1		T2		Condition × phase	T1 vs. T2	
Measure	Condition	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI	*F* (1, 65)	*F* (1, 65)	η_p^2
Workplace satisfaction	L	3.77 (.80)	[3.41, 4.14]	4.24 (.77)	[3.93, 4.54]	1.44	2.56*	.04
	G	3.77 (1.29)	[3.39, 4.14]	4.54 (.99)	[4.24, 4.85]		4.21***	.06
Concentration	L	4.62 (1.33)	[4.16, 5.07]	4.38 (1.39)	[3.91, 4.86]	9.15**	.79	.01
	G	3.90 (1.36)	[3.44, 4.37]	4.79 (1.36)	[4.31, 5.27]		3.33**	.05
Air quality	L	4.29 (1.19)	[3.79, 4.79]	4.21 (1.20)	[3.67, 4.73]	4.21*	.37	.01
	G	3.64 (1.71)	[3.13, 4.14]	4.24 (1.82)	[3.71, 4.77]		2.51*	.04
Productivity	L	4.95 (.93)	[4.59, 5.31]	4.61 (.85)	[4.25, 4.97]	7.17*	1.74†	.03
	G	4.63 (1.07)	[4.27, 5.00]	5.02 (1.14)	[4.64, 5.39]		1.95†	.03

Note. L = lean condition; G = green condition. T1 took place 8 weeks before the introduction of the plants in the green condition and T2 3 weeks after the plants.
† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

concentrate after the introduction of plants, $F(1, 65) = 11.11$, $p = .001$, 95% CI [.25, .99], $\eta_p^2 = .15$, 90% CI [.04, .27], whereas in the lean office there was no difference over time, $F(1, 65) = .63$, $p = .431$, 95% CI [−.51, .22].

Air quality. Analysis of perceived air quality revealed a significant interaction between office design and study phase, $F(1, 65) = 4.21$, $p = .044$, $\eta_p^2 = .06$, 90% CI [.00, .17]. In the green office participants perceived an increase in air quality after the introduction of the plants, $F(1, 65) = 6.32$, $p = .014$, 95% CI [.09, .77], $\eta_p^2 = .09$, 90% CI [.01, .21], but not in the lean office, $F(1, 65) = .14$, $p = .711$, 95% CI [−.40, .27].

Subjective productivity. Analysis of participants' subjective ratings of their own productivity revealed a significant interaction effect between type of office design and study phase, $F(1, 57) = 6.83$, $p = .011$, $\eta_p^2 = .11$, 90% CI [.01, .24]. In the green office there was an increase in subjective productivity after the introduction of the plants, $F(1, 57) = 3.81$, $p = .056$, 95% CI [−.01, .54], $\eta_p^2 = .06$, 90% CI [.00, .18], whereas in the lean condition there was a decrease in subjective productivity, $F(1, 57) = 3.04$, $p = .086$, 95% CI [−.51, .03], $\eta_p^2 = .05$, 90% CI [.00, .16], although both simple effects did not reach the critical significance level.

Multilevel analysis. Because attrition and missing data meant that the final sample in Study 1 was quite small, an additional multilevel analysis was conducted. In this regard, longitudinal data can be seen as multilevel data, with repeated measures nested within individuals (Hox, 2002). An advantage of multilevel analysis of longitudinal data is the ability to handle missing data, as multilevel regression models do not assume equal numbers of observations (unlike ANOVA; Snijders, 1996). That is, it is not a problem if the available measurements are not the same for all individuals. The multilevel analysis was based on the total sample of $N = 153$ (compared with $N = 67$ for the ANOVAs; see Table 1). The pattern of results for the multilevel analysis was identical to the ANOVA for all dependent variables; that is, a significant main effect of study phase was found for workplace satisfaction, and significant interaction effects (Study Phase × Office Design) were found for concentration and perceived air quality. All significant effects were in the same direction as in the ANOVAs, which are reported here for reasons of interpretability. Further details regarding this analysis are available as supplemental data.

Discussion

This experiment compared the productivity and well-being of employees in two office environments: one where the office remained lean, the other where the office was landscaped with plants. Relative to the lean condition, participants in the green office reported improved air quality, enhanced levels of concentration, and showed improved productivity 3 weeks after the introduction of plants on the workfloor. Unexpectedly, however, satisfaction with the work environment improved in both office types. These findings emerged from multivariate analyses but were also confirmed by multilevel analysis that was conducted with a larger sample (i.e., the *total* sample; see Table 1).

The reason for the improvement of workplace satisfaction in both conditions is likely to be related to a limitation of Study 1. Both green and lean conditions were located on the same floor in an open plan office and although participants in the lean space (the control condition) could not see any plants from their workstation, it is possible that they might have been influenced by the presence of the plants on the floor as they walked past them on their way to their desks. We therefore sought to reduce the potential permeability between the different conditions in Study 2. In addition, we included a process measure of disengagement as a potential contributing factor to well-being and performance, for reasons explained in more detail below. This study also aimed to enhance our assessment of productivity by using a direct measure of employee performance, rather than recording workers' perceptions of their own productivity (Peters & Waterman, 2004). Finally, this next study also measured long-term effects of the presence of plants on the workfloor.

Study 2

Study 2 was conducted within the service center of a large health insurance company in Zwolle, The Netherlands. Employees were mainly involved in giving insurance and declaration advice to clients over the telephone. We used a discrete control condition to address the limitation of Study 1. The study took place in two open-plan offices located on different floors within the same building. In this way—and unlike Study 1—employees in the lean condition were unlikely to be influenced by the presence of plants

in the green condition. In contrast to Study 1, participants were less well paid, had less autonomy, and operated under conditions of greater job surveillance. Nevertheless, the company's clear and monitored job stratification allowed for straightforward comparison between office workers of different status. The main goal of the study was to examine whether enrichment of office space had any impact on employees' satisfaction with the work environment, concentration levels, perceived air quality, and objective productivity levels over the short-term (after 2 weeks) and the long-term (after 3.5 months).

Objective productivity measures were available from the company, which continuously monitored the performance of its agents. Unlike almost all other types of office work, call center agents have their work routinely timed. The key productivity measure is seen to be average handling time (AHT, i.e., the average duration of a call). This measure has three components: the duration of each call (talk-time); the time the agent places the caller on hold (hold-time); and the time between successive calls that is needed to report the necessary details within the system (after call work, ACW). Office work of service center agents requires concentration, verbal communication, logical thinking under time pressure, visual attention, and the use of computer software. The rationale behind the AHT measure is that when a call center agent concentrates better or becomes more motivated, they will increase their performance which is likely to result in a shorter AHT. Limitations of the measure are that shorter AHT can clearly arise from other factors and that it is a measure of efficiency rather than quality.

We also collected additional data with a view to examining mechanisms that, in the event of our main hypotheses being confirmed, might account for the effects of plants on the workfloor. More specifically, we examined whether disengagement with the office environment could be a potential mediator for outcomes of environmental satisfaction (i.e., perceived air quality, perceived concentration, and workplace satisfaction).[3] This focus on disengagement speaks to the relational and managerial consequences of plants, as discussed in the beginning of the article. In short, enrichment of the office would signal managerial care and attention, which should stimulate employees to become more physically, cognitively, and emotionally engaged in their work. This will reduce the risk of disengagement (as measured by feelings of apathy, boredom, distractedness and tiredness) within the office. In turn, reduced disengagement should result in enhanced concentration levels and a greater sense of belonging within the workplace (i.e., workplace satisfaction).

With regard to perceived air quality, the mediation can work in two directions. First, feelings of disengagement within the office space may result in a *perception* of poor air quality. That is, employees may partly attribute feelings of apathy, tiredness, or lack of attention (all indicators of disengagement) to the poor air quality in the office. The enriching presence of plants may reduce feelings of disengagement, resulting in a perceived enhancement of the air quality within the office. Second, the presence of plants might have a direct (physiological) effect on air quality, which in turn enhances attention and focus thereby reducing (physical) disengagement. Importantly, the use of a cross-lagged panel model allowed for simultaneous examination of both these pathways.

Method

Design. A 2 × 3 mixed design was employed in the study. *Office design* was manipulated as a between-subjects variable (lean, green). The office designs were located on different floors within the same building in two identical open-plan spaces. In the lean space participants had no plants in their office; in the green space plants were introduced into the office such that each employee had at least one plant in direct view. *Study phase* was a within-subjects variable, with measures administered before the introduction of the plants (T1), 2 weeks after their introduction (T2), and 3.5 months after their introduction (T3).

Participants and procedure. The study was conducted in two open-plan offices located on different floors of a large office building. Both floors were approximately 360 m^2. All employees in both offices were invited to take part in the longitudinal study ($N = 191$). They received paper-and-pencil questionnaires from their manager. One-hundred and 43 employees returned completed questionnaires via a collection box (75% response rate). Five weeks later—in the green office—an interior designer installed an array of green, large-leafed plants (average height 90 cm) around the workfloor. There was an average of one plant per three desks. In the lean office no changes to the working environment were made. At T2, 2 weeks after the plants were installed in the green space, all employees were invited to complete a second paper-and-pencil questionnaire. One-hundred and 34 employees completed this, representing a 70% response rate. At T3, 3.5 months after the plants were introduced, all employees received a third questionnaire, which was completed by 111 people, representing a 58% response rate. In order to match questionnaires to the right person, all employees received a unique code at T1 and these codes were used throughout the study.

The total sample consisted of 172 participants (see Table 3 for numbers per condition). Participants in this sample completed either one, two, or three waves of the study. After listwise deletion, the final sample consisted of 81 participants who completed all three waves of the study (15 men and 66 women), ranging in age from 21 to 59 years ($M = 34.86$, $SD = 10.02$). Analyses revealed no differences (on any measure) between the full samples at each time point and the final sample that was retained for analysis.

Besides the questionnaire data, we also used the company's own measures of productivity to assess how the presence of plants affected performance. Productivity measures assessed how quickly an employee handled a call (time in minutes). For 48 employees who were working in the lean ($N = 26$) and green ($N = 22$) offices, productivity measures were available across the three time-points.

Measures. The questionnaire that participants completed included 14 questions assessing four key constructs. Participants responded on a 7-point scale, ranging from 1 (*completely disagree*) to 7 (*completely agree*). *Workplace satisfaction* was measured with four items ($\alpha_{T1} = .88$; $\alpha_{T2} = .84$; $\alpha_{T3} = .87$; e.g., "I feel at home in the office," after Knight & Haslam, 2010b). *Concentration* was measured with one item, that is, "In the office I am able to concentrate well," after Knight & Haslam, 2010b). *Air quality* was

[3] These data were not included in our initial analyses of results, but were conducted post hoc in light of comments from reviewers.

Table 3
Sample Sizes per Wave and Condition for Study 2

Condition	T1	T2	T3	Total sample (completed either one, two or three waves of the study)	Final sample (after listwise deletion)
Lean	33	36	31	47	21
Green	110	98	80	125	60
Total	143	134	111	172	81

measured with three items ($\alpha_{T1} = .70$; $\alpha_{T2} = .78$; $\alpha_{T3} = .84$; e.g., "The air in the office is dry;" reverse-coded, after Knight & Haslam, 2010b). *Disengagement* was measured with six items ($\alpha_{T1} = .83$; $\alpha_{T2} = .83$; $\alpha_{T3} = .84$). Participants were asked to what extent they had particular symptoms (i.e., "feeling apathetic," "feeling bored," "being easily distracted," "not being challenged," "feeling worried," and "feeling tired") in the office during the previous week and were asked to provide responses on a 5-point scale, ranging from 1 (*not at all*) to 5 (*very often*). Additional questions asked participants to provide demographic details—specifically, their *age*, *gender*, and number of *work years* at the company.

Productivity measures were provided by the company, which used AHT as the main indicator of productivity. AHT is the total time (measured in minutes) employees spend on the phone with clients, where a shorter handling time is taken to indicate greater productivity as the employee will be able to handle more clients per day. AHTs (the average for 2 weeks) were compared between the lean and green offices across the three time-points.

Results

Analytic strategy. Scores on all measures were subjected to two-way analysis of variance (ANOVA) with office design (lean, green) as a between-subjects factor and study phase as a within-subjects factor (T1, T2, T3). This was followed up by simple contrast analysis to test for the overall effects of plants on the workfloor (T1 vs. T2, T3) and to establish whether the changes hold up in the long term (T2 vs. T3). Relevant means and statistics are presented in Table 4. To test for possible mechanisms that underlie the positive effects of green workspaces a cross-lagged panel model (CLPM) for longitudinal data, based on a structural equation modeling (SEM) approach, was used. The advantages of the CLPM are that it allows time for causes to have their effects, allows for stronger inference about the direction of causation in comparison to models using cross-sectional data, and reduces the probable parameter bias that arises when using cross-sectional data (Selig & Preacher, 2009).

Demographics and premeasures. First, we tested whether there were any differences across the two office designs (*lean* vs. *green*) with regard to demographics of the participants. No significant differences were found on gender, $\chi^2(1) = .001$, $p = .979$, age, $t(79) = .58$, $p = .565$, or on work years for the company, $t(79) = .02$, $p = .981$. Second, we tested to see whether there were any differences across the two floors in the premeasures. No significant differences were found on any of the dependent variables, $ts(158) < 1.20$, $ps > .23$.

Workplace satisfaction. Analysis of participants' workplace satisfaction revealed a significant interaction between office de-

Table 4
Study 2: Employees' Perceptions of Satisfaction, Concentration, and Air Quality and Objective Productivity in Lean and Green Office Environments

		Phase						Effects			
		T1		T2		T3			T1 vs. T2, T3		T2 vs. T3	
Measure	Condition	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI	Condition × phase *F* (2, 158)	*F* (1, 79)	η_p^2	*F* (1, 79)	η_p^2
Workplace satisfaction	L	5.10 (1.20)	[4.52, 5.69]	4.73 (1.02)	[4.35, 5.11]	4.93 (1.06)	[4.48, 5.37]	7.40***	1.30	.02	1.44	.02
	G	4.91 (1.18)	[4.61, 5.20]	5.52 (.70)	[5.35, 5.70]	5.40 (.83)	[5.18, 5.55]		22.18***	.22	2.10	.03
Concentration	L	4.88 (1.58)	[4.10, 5.65]	4.81 (1.51)	[4.14, 5.48]	5.10 (1.50)	[4.41, 5.83]	.93	.08	.00	1.17	.01
	G	4.52 (1.56)	[4.14, 4.91]	4.97 (1.30)	[4.64, 5.30]	4.92 (1.41)	[4.56, 5.27]		6.35*	.07	.10	.00
Air quality	L	4.18 (1.71)	[3.44, 4.93]	3.78 (1.66)	[3.04, 4.51]	4.25 (1.39)	[3.55, 4.95]	3.67*	.31	.00	2.16	.03
	G	3.68 (1.43)	[3.31, 4.05]	4.29 (1.43)	[3.93, 4.65]	4.21 (1.41)	[3.86, 4.55]		13.91***	.15	.29	.00
Objective productivity[a]	L	7.65 (1.42)	[6.99, 8.29]	7.28 (1.12)	[6.90, 7.67]	7.67 (.98)	[7.30, 8.05]	.19[b]	.31	.01	4.84*	.10
	G	7.53 (.88)	[6.83, 8.24]	6.97 (.76)	[6.55, 7.38]	7.53 (.93)	[7.13, 7.95]		.83	.02	9.12**	.17

Note. L = lean condition; G = green condition. T1 took place 5 weeks before the introduction of the plants, T2 2 weeks after the plants, and T3 3.5 months after the plants.
[a] Time in minutes, where shorter time indicates larger productivity. [b] *F* value based on *df*s (2, 92).
* $p < .05$. ** $p < .01$. *** $p < .001$.

sign and study phase, $F(2, 158) = 7.40$, $p = .001$, $\eta_p^2 = .09$, 90% CI [.02, .15]. Simple contrasts showed that in the green condition participants became significantly more satisfied with their work environment after the introduction of the plants (T1 vs. T2, T3), $F(1, 79) = 22.18$, $p < .001$, 95% CI [.26, .65], $\eta_p^2 = .22$, 90% CI [.10, .34]. In addition, this effect did not significantly decrease in the long term (T2 vs. T3), $F(1, 79) = 2.10$, $p = .151$, 95% CI [−.20, .03]. In the lean condition there was no difference over time (T1 vs. T2, T3), $F(1, 79) = 1.30$, $p = .256$, 95% CI [−.61, .16].

Concentration. Analysis of responses on this measure revealed a nonsignificant interaction between office design and study phase, $F(2, 158) = .93$, $p = .40$.

Air quality. Analysis of perceived air quality revealed a significant interaction between office design and study phase, $F(2, 158) = 3.67$, $p = .028$, $\eta_p^2 = .05$, 90% CI [.00, .10]. Simple contrasts showed that participants in the green condition perceived an increase in air quality after the introduction of the plants, (T1 vs. T2, T3), $F(1, 79) = 13.91$, $p < .001$, 95% CI [.22, .71], $\eta_p^2 = .15$, 90% CI [.05, .27]. In addition, this effect did not significantly decrease in the long term (T2 vs. T3), $F(1, 79) = .29$, $p = .593$, 95% CI [−.28, .16]. In the lean condition there was no difference over time (T1 vs. T2, T3), $F(1, 79) = .31$, $p = .575$, 95% CI [−.64, .36].

Productivity. Analysis of objective measures of productivity (time in minutes, where shorter time means more productive) revealed a main effect for study phase, $F(2, 92) = 3.93$, $p = .023$, $\eta_p^2 = .08$, 90% CI [.01, .16]. However, the simple contrasts for *study phase* showed that the change in productivity was not significant over time (T1 vs. T2, T3), $F(1, 46) = 1.11$, $p = .298$, 95% CI [−.17, .53], although there was a difference between the postmeasures (T2 vs. T3), $F(1, 46) = 13.81$, $p = .001$, 95% CI [−.53, −.16], $\eta_p^2 = .23$, 90% CI [.07, .38], as participants showed a decrease in productivity between T2 and T3. As this change only happened 3.5 months after the introduction of the plants and in both types of office design, it is unlikely that this is related to the study. The main effect of study phase was not qualified by office design, $F(2, 92) = .19$, $p = .829$.

Multilevel analyses. As the final sample of Study 2 was relatively small due to attrition, an additional multilevel analysis was conducted. The multilevel analysis was based on the total sample of $N = 172$ (compared with $N = 81$ for the ANOVAs; see Table 3). As in Study 1, the pattern of results was similar for both analyses on all dependent variables, that is significant interaction effects (Study Phase × Office Design) in the same direction were found for workplace satisfaction and perceived air quality, whereas no significant interaction was found for concentration. Further details regarding this analysis are available as supplemental data. For reasons of interpretability, it was chosen to report the ANOVA results.

Cross-lagged panel model (CLPM). AMOS software was used to test a CLPM for longitudinal data, based on a structural model with measured variables. This type of model allows for simultaneous examination of longitudinal influences of one construct on another, and vice versa, while also controlling for contemporaneous associations between constructs, and the stability of each construct over time. A separate model was tested for each of the dependent variables (i.e., workplace satisfaction, concentration, and perceived air quality). Figure 1 provides a generic illustration of these models. The model specified condition (0 = lean; 1 = green) as a predictor of disengagement ($M_{t1} = 2.23$, $SD_{t1} = .99$; $M_{t2} = 2.18$, $SD_{t2} = .97$; $M_{t3} = 2.16$, $SD_{t3} = .91$) and an outcome variable (Y) at Time 2 to examine possible routes of mediation. The relations between disengagement and an outcome variable were specified as cross-lagged effects, which indicates the prospective effect of one variable on the other (e.g., the effect of disengagement at T1 on an outcome variable at T2), after controlling for their stability across time (e.g., the effect of an outcome variable at T1 on an outcome variable at T2). We accounted for variance due to specific measurement occasions by correlating the residual variances within waves (e.g., the residual of disengagement at T2 and the residual of an outcome variable at T2; cf. Cole & Maxwell, 2003).

To determine the fit of the proposed model, we report the chi-square goodness of fit test, the comparative fit index (CFI) and the root mean squared error of approximation (RMSEA). A small, nonsignificant chi-square value indicates optimal fit, whereas a large, significant chi-square indicates poor fit. Values higher than .95 for the CFI indicate that the tested model provides an adequate fit to the data, as does an RMSEA value lower than .06 (see Hu & Bentler, 1999). The fit values for each of the outcome variables were satisfactory (see Table 5).

Model workplace satisfaction. Condition had a significant direct effect on disengagement at Time 2 ($\beta = -.15$, $p = .040$) and on workplace satisfaction at Time 2 ($\beta = .37$, $p < .001$; see Figure 2). This indicates that, compared with the lean offices, employees in the green offices became less disengaged and more satisfied with their workplace after the introduction of the plants. The cross-lagged effects showed that disengagement prospectively predicted workplace satisfaction (T1 to T2, $\beta = -.19$, $p = .025$; T2 to T3, $\beta = -.24$, $p = .019$) whereas workplace satisfaction did

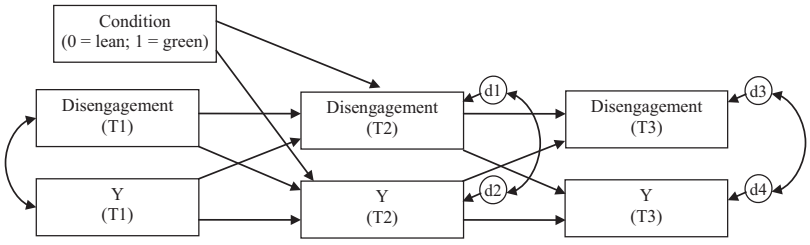

Figure 1. Cross-lagged regression model of the relations between disengagement and an outcome variable (Y). Condition is added as a predictor of both disengagement and an outcome variable (Y) at Time 2 to examine possible routes of mediation. Residual variances (i.e., disturbances) are denoted from d1 to d4.

Table 5
Model Fit for Each of the Outcome Variables

Outcome variable	χ^2	*df*	*p*	CFI	RMSEA
Workplace satisfaction	8.04	6	.24	.99	.066
Concentration	6.56	6	.36	.99	.034
Air quality	5.51	6	.48	1.00	.000

Note. CFI = comparative fit index; RMSEA = root mean square error of approximation.

not prospectively predict disengagement (T1 to T2, β = −.03, *ns*; T2 to T3, β = .02, *ns*). The cross-lagged effects indicate that lower levels of disengagement made employees more satisfied with their workplace.

In sum, the model suggests that it is appropriate to regard disengagement as a mediator of the relationship between condition and workplace satisfaction (rather than examining workplace satisfaction as a mediator between condition and disengagement). That is, working in a green office (compared with a lean office) tends to decrease employees' levels of disengagement which in turn has a positive effect on their workplace satisfaction.

Model concentration. As with the previous model, condition had a direct effect on disengagement at T2 (β = −.16, *p* = .026), indicating that participants in the green workspace reported less disengagement after the introduction of plants than participants in the lean condition (see Figure 3). However, no direct effect of condition was found on concentration at T2 (β = .04, *ns;* which is in line with the reported nonsignificant interaction for the ANOVA on concentration). The cross-lagged effects for disengagement on concentration were significant between T2 and T3 (β = −.19, *p* = .030), but not between T1 and T2 (β = −.06, *ns*). Similarly, the cross-lagged effects for concentration on disengagement were significant between T2 and T3 (β = −.16, *p* = .040), but not between T1 and T2 (β = −.12, *p* = .114). Although condition had no significant direct effect on concentration at T2, results suggest that condition influences concentration (at T3) *indirectly* via disengagement (at T2). Accordingly, the model suggests that disengagement mediates the relationship between condition and concentration (rather than concentration being a mediator between condition and disengagement). In other words, working in a green office (rather than a lean office) decreases employees' levels of disengagement which in turn has a positive effect on their concentration.

Model of perceived air quality. Condition had a significant effect on disengagement at T2 (β = −.16, *p* = .029) and on perceived air quality at T2 (β = .18, *p* = .020; see Figure 4). This indicates that, compared to the lean offices, employees in the green offices became less disengaged and perceived the air quality to be improved after the introduction of the plants. As with the model predicting workplace satisfaction, the cross-lagged effects of the current model showed that disengagement prospectively predicted perceived air quality (T1 to T2, β = −.17, *p* = .030; T2 to T3, β = −.17, *p* = .050) whereas perceived air quality did not prospectively predict disengagement (T1 to T2, β = −.11, *p* = .144; T2 to T3, β = .03, *ns*). These cross-lagged effects indicate that lower levels of disengagement lead employees to perceive air quality to be better. In sum, these results suggest that it is appropriate to see disengagement as a mediator of the relationship between condition and air quality (rather than seeing air quality as a mediator between condition and disengagement). That is, working in a green office (rather than a lean one) leads to a reduction in levels of disengagement which in turn has a positive effect on perceived air quality.

Discussion

Study 2 extended the findings of Study 1 by focusing on the long-term effects of the presence of plants in the workspace. In line with results from Study 1, green office space was associated with enhanced workplace satisfaction and an increase in perceived air quality in the short-term (2 weeks) and the long-term (3.5 months). In contrast, however, there were no significant changes over either time period in the lean condition. Reported concentration levels seemed to increase within the green condition (see Table 4), although we did not find that concentration increased *relative to* the lean condition (i.e., there was no significant interaction effect). Indeed, the multilevel analyses (which was conducted among a larger sample, i.e., the *total* sample; see Table 3) on this measure did not show a significant increase of concentration in the green condition either. Importantly, however, the multilevel analysis found exactly the same pattern of results as the multivariate analyses for measures of workplace satisfaction and perceived air quality.

In this study, we also conducted analyses to explore possible mechanisms that might account for the impact that plants have in the workplace. Results suggested that a green office leads to more engagement among employees, which in turn has a positive impact on their satisfaction with the workplace, their concentration, and their perceptions of air quality.

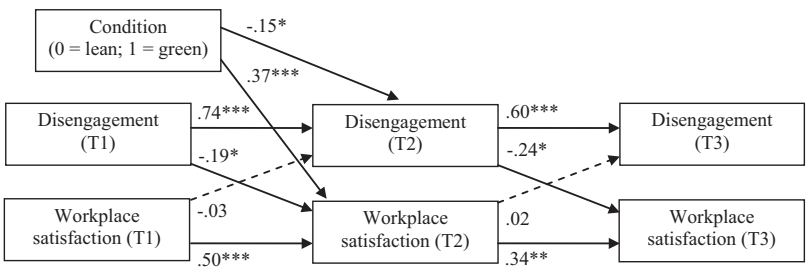

Figure 2. Study 2: Cross-lagged regression model of workplace satisfaction. Standardized parameters are reported. * $p < .05$. ** $p < .01$. *** $p < .001$.

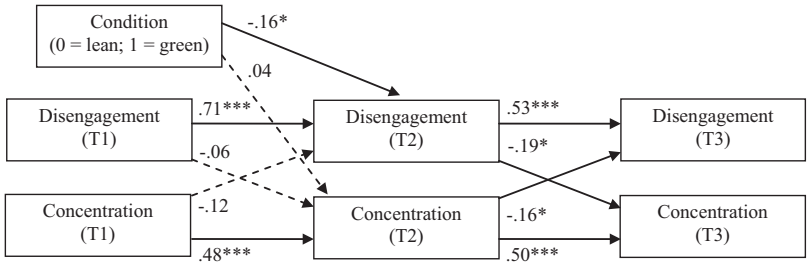

Figure 3. Study 2: Cross-lagged regression model of concentration. Standardized parameters are reported. * $p < .05$. ** $p < .01$. *** $p < .001$.

However, no effects of office design were found on our "objective" measure of productivity. Interpreting this null effect is complicated by the fact that time on a call (AHT) is an ambiguous performance measure. Although it may be better for operatives to deal with calls quickly in some cases, in the present case of operatives taking calls concerning health care insurance it is entirely possible that—especially from a customer's point of view—those who spend longer on calls are delivering superior service. Thus, AHT addresses the first two problems of performance measurement (accuracy and objectivity) but not necessarily the third (meaningfulness). Accordingly it is a moot question whether this is a good measure of productivity at all (Baldry & Hallier, 2010; Dixon, 2009; Peters & Waterman, 2004; Vischer, 2005). To address this issue of measuring performance on office-based tasks in a more appropriate fashion, we conducted a third study.

Study 3

In our third field experiment we revisited the concept of office space productivity using metrics specifically developed to measure office space productivity (Knight & Haslam, 2010b). These methods were adopted for two main reasons. First, the measures of attention to detail, information processing and information management aligned closely with tasks expected of auditors. Second, as noted by Knight and Haslam (2010b), there is a dearth of viable alternative productivity measures. The study was conducted among employees of a large consultancy organization in London and took place within their own working environment. Participants were randomly assigned to one of two experimental conditions (lean or green office design) where they performed two standard productivity tasks in order to gauge the impact of office design on productivity.

Method

Participants. Thirty-three employees participated in the experiment (16 men, 17 women), ranging in age from 22 to 33 years ($M = 28.0$, $SD = 3.23$), with 17 participating in the lean condition and 16 in the green condition. Potential participants were recruited from the same floor where the experiment took place (62% of the sample), as well as on other floors within the same building where similar work was performed (38% of the sample). Participation was voluntary and unpaid.

Materials and procedure. The field experiment was conducted in an open plan area where two different office designs were implemented (lean, green). In every trial (three in total), participants congregated in a meeting room at the end of the working day (6 p.m.). The experimenters explained to the participants that they would take part in a study examining performance on analytical, processing, and intellectual tasks. Participants were also told that they needed to complete the tasks as quickly and accurately as possible. After the instructions participants were randomly assigned to an experimental condition (lean or green) and to a workstation.

In both experimental conditions the office space consisted of rows of three to five workstations, separated by vertical dividers (height 45 cm). The workstations consisted of a rectangular desk (220 cm × 80 cm) and a comfortable office chair on castors. Each desk housed a computer monitor and a telephone. In the lean condition, no further additions to the office space were made. The green office space also contained eight large green plants (average height 90 cm). Because several participants were taking part in the study at the same time, the view of the plants was not exactly the same for each participant. However, each participant in the green condition could see at least three plants from the workstation.

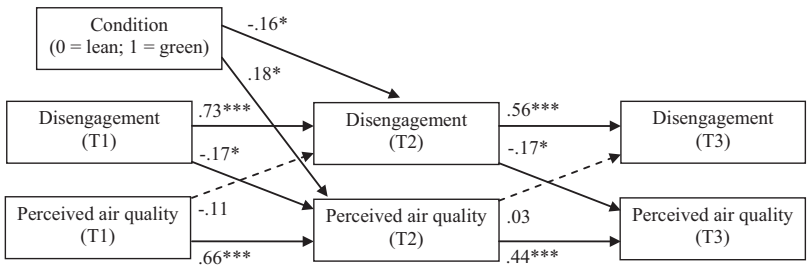

Figure 4. Study 2: Cross-lagged regression model of perceived air quality. Standardized parameters are reported. * $p < .05$. ** $p < .01$. *** $p < .001$.

As part of the experiment, each desk contained two piles of papers, with each pile containing a different experimental task. Before starting, participants were asked to briefly describe their immediate office environment on a separate sheet (*quality of workspace*). This item was used as a manipulation check to measure whether the perceived quality of workspace indeed differed across conditions. After this, participants performed an information management and processing task followed by a vigilance task. The experimenters recorded the time participants took to complete each using a stopwatch.

Experimental tasks and measure. All responses on the manipulation check on *quality of workspace* were independently coded by two individuals who were blind to the participants' experimental condition and who rated each response on a scale from 1 (*very negative*) to 5 (*very positive*). Interrater agreement was excellent (ICC = .90) based on Cicchetti and Sparrow's (1981) criteria (ICC > .74). The ratings were used to calculate an average score on perceived quality of workspace for each condition.

The first task was an *information management and processing task.* Participants were asked to work with a shuffled pile of corporate memoranda based on a fictitious company. They had to imagine that they were employees of this company and (a) sort the memoranda into chronological order (information management), and then (b) answer 15 multiple-choice questions based on the data contained in the memos (information processing). The time taken to complete the task (in minutes) was measured as well as the number of errors (wrongly answered multiple choice questions).

After this, participants performed a *vigilance task*. For this purpose they were each given an A4 photocopy of the same magazine article and asked to cross out and count all the lower case letter *b*s that were on the page. The time taken to complete the task (in minutes) was measured as well as the number of errors (missed *b*s). In both cases the participants were told that they needed to perform the tasks as quickly and as accurately as possible.

Results

Manipulation check. Univariate analysis of variance (ANOVA) revealed a significant effect of office design on perceived quality of workspace, $F(1, 28) = 6.25$, $p = .022$, full $\eta^2 = .18$, 90% CI [.02, .37]. Participants in the green condition rated the office environment more positively ($M = 3.32$, $SD = .87$, 95% CI [2.82, 3.82]), compared with participants in the lean condition ($M = 2.41$, $SD = 1.15$, 95% CI [1.79, 3.02]).

Productivity. To analyze the effect of office design on productivity a MANCOVA was performed, with time taken to complete the two tasks as dependent variables. Office design (lean, green) was the between-subjects factor. The numbers of errors made on either task were included as covariates in the analysis. These covariates were included in order to measure a possible change in efficiency, without loss of quality of work. See Table 6 for descriptives and intercorrelations for all variables.

Analysis of productivity revealed a significant effect of the covariates, the number of errors on the vigilance task, $F(2, 28) = 4.89$, $p = .015$, $\eta_p^2 = .26$, 90% CI [.03, .42], and the number of errors on the information processing task, $F(2, 28) = 6.59$, $p = .005$, $\eta_p^2 = .32$, 90% CI [.07, .48]. There was also a significant effect of office design, controlling for the covariates, $F(2, 28) = 4.80$, $p = .016$, $\eta_p^2 = .26$, 90% CI [.03, .42]. Next, separate univariate ANCOVAs on the outcome variables were calculated. There was a significant effect of the covariate (number of errors made) on time taken to complete the *vigilance task*, $F(1, 30) = 7.69$, $p = .009$, $\eta_p^2 = .20$, 90% CI [.03, .39]. There was also a significant effect of office design on time taken to complete the vigilance task, controlling for the covariate, $F(1, 30) = 7.91$, $p = .009$, $\eta_p^2 = .21$, 90% CI [.03, .39]. Participants in the green condition took less time to complete the task (adjusted $M = 5.39$, $SD = 1.40$, 95% CI [4.73, 6.05]), compared with participants in the lean condition (adjusted $M = 6.67$, $SD = 1.43$, 95% CI [6.03, 7.31]). With regard to the *information processing task*, the effect of the covariate (numbers of errors made) was not significant, $F(1, 30) = 2.50$, $p = .124$, and a nonsignificant effect was found for office design on time taken to complete the information processing task, controlling for the covariate, $F(1, 30) = 3.04$, $p = .092$. Participants in the green condition took less time to complete the task (adjusted $M = 17.39$, $SD = 3.85$, 95% CI [14.89, 19.89]), compared with participants in the lean condition (adjusted $M = 20.39$, $SD = 5.87$, 95% CI [17.96, 22.81]). Separate ANOVAs showed no effects of office design on the number of errors made on either task, Fs(1, 31) = .95, .60, ps = .34, .45.

Discussion

In comparison to the subjective measures used in Study 1 and the corporate measures used in Study 2, this third study employed a less problematic measure of productivity. Here the results un-

Table 6
Study 3: Intercorrelations and Descriptives for Office Design, Quality of Workspace, and Time Taken and Numbers of Errors Made in the Vigilance and Information Processing Task

	M	*SD*	1	2	3	4	5	6
1. Office design (0 = lean; 1 = green)	.48	.51	—					
2. Quality of workspace	2.83	1.12	.42*	—				
3. Time vigilance task[a]	6.05	1.59	−.48**	−.22	—			
4. Errors vigilance task	16.91	7.31	.17	.08	−.47**	—		
5. Time information processing task[a]	18.94	5.10	−.26	−.07	.12	−.28	—	
6. Errors information processing task	1.27	1.63	.14	.10	−.50**	.14	.23	—

[a] Time in minutes, where shorter time indicates greater productivity.
* $p < .05$. ** $p < .01$.

ambiguously indicated that participants who worked in green office space were more productive than their counterparts who worked in a lean office space. Tasks were completed faster and—importantly—without any accompanying rise in errors.

General Discussion

Three field studies were conducted to compare the effects of working in an enriched green work environment with those of working in a lean workspace. A consistent pattern emerged whereby workers in green workspaces had a more positive orientation to their work environment and to their work than those in lean workspaces (for a summary see Table 7). That is, enriching a previously lean office with plants served to significantly increase workplace satisfaction, self-reported levels of concentration, and perceived air quality. Moreover, these improvements were sustained over both the short-term (Study 1) and the long-term (Study 2). Significant interactions were also found on four of six occasions. Crucially, enriching space also improved perceived productivity in Study 1 and actual productivity in Study 3, and this is something of a touchstone for business theorists (Allen, 2011). Data from the present findings indicate that a green working environment is consistently more enjoyable for employees, more conducive to concentration, and more productive for the business than its lean equivalent. Indeed, simply enriching a previously spartan space with plants served to increase productivity by 15%—a figure that aligns closely with findings in previously conducted laboratory studies (Knight & Haslam, 2010b).

Furthermore, our exploration of possible mechanisms underlying the beneficial effects of indoor plants suggests that a green office leads to more *work engagement* among employees, which in turn has a positive impact on their satisfaction with the workplace, their concentration, and their perceptions of air quality. It seems that enhanced engagement increases positive ratings of the work environment in general, which might be the result of people becoming more physically, cognitively, and emotionally involved in their work (Kahn, 1990). There is some support from related experimental work which suggests that indoor plants can lead students to feel more comfortable (Wiers-Jenssen et al., 2002) and hence to rate their course and course environment more positively (Doxey, Waliczek, & Zajicek, 2009). Within our study we have been able to show this positive effect of plants on the work environment via maintained engagement over time.

Table 7
Changes of Employees' Satisfaction, Concentration, Perceived Air Quality, and Productivity in Lean and Green Office Environments Across all Studies

	Study 1		Study 2		Study 3
Dependent variable	L	G	L	G	L vs. G
Workplace satisfaction	+	+ +	0	+ +	Not tested
Concentration	0	+ +	0	+	Not tested
Perceived air quality	0	+	0	+ +	Not tested
Productivity[a]	(−)	(+)	0	0	+[b]

Note. L = lean condition; G = green condition. + + = positive change at $p < .01$. + = positive change at $p < .05$. (+) = positive change at $p < .10$. (−) = negative change at $p < .10$. 0 = no change ($p > .10$). This table was based on simple effect analyses in Studies 1 (T1 vs. T2) and 2 (T1 vs. T2, T3) and the MANCOVA in Study 3.
[a] Productivity was measured in different ways across the studies. [b] This effect refers to the difference between the lean and the green condition.

The mediating role of disengagement on concentration is also consistent with the possibility that plants have a restorative effect on attention as proposed by ART. Disengagement (as measured by items such as "feeling apathetic," "feeling bored," and "not being challenged") may be linked to attentional fatigue as a result of hard work and an inability to concentrate (Kaplan, 1995). In sum, the mediating role of work engagement on workplace satisfaction, perceived air quality and concentration is in line with explanations that point to the importance of managerial care and attention. At the same time, the effects on concentration and engagement are consistent with restorative effects as proposed by ART. Of course, these processes are not mutually exclusive: they may together contribute to the beneficial effects of indoor plants, either independently or jointly.

Beyond the processes involved, our findings represent an advance on previous studies by providing a direct, quantitative assessment of the benefits of a lean approach to office space relative to those of a green alternative. Although the patterns observed here align with previous qualitative (e.g., Duffy & Hutton, 1998; Elsbach, 2003; Myerson, 2007; Vischer, 2005) and quantitative studies (e.g., Knight & Haslam, 2010b), the particular advantage of the present research is that it uses an experimental approach to manipulate relevant variables *in the workplace* and *over the long-term* with consistent effects recorded regardless of the status of the participant. In this, the present study develops the theme that the impact of enrichment is universal and long term (Knight & Haslam, 2010a; Peters & Waterman, 2004; Zeisel, 2006). As a consequence, these data simultaneously increase our confidence in the causal status of our independent variables and the ecological validity of our conclusions.

Results from the current studies are also in line with previous studies into workplace performance as well as with qualitative investigations into the elements that comprise an effective workspace. Accordingly, they point to the value of introducing plants into a workspace for the benefit of employees *as well* as for the financial health of the organization. This conclusion is at odds with the present economic and political zeitgeist as well as with modern management techniques, yet it nevertheless identifies a pathway to a more enjoyable, more comfortable, and a more profitable form of office-based working (Baldry, Bain, & Taylor, 1998; Cohen, 2007; Crampton, 2011; Elsbach, 2003; Taylor, 1911; Zelinsky, 2006).

Limitations and Further Research

Despite the consistency of findings—both internally and with other psychological studies—this research has a number of limitations. First, we should consider why two of the six predicted interactions were not significant. The first of these concerned satisfaction with the workspace in Study 1: Satisfaction increased in both the lean *and* green conditions. We argued that the unexpected rise in satisfaction in the lean condition may have been due to the exposure to plants en route to workstations, making the environment more attractive to look at. When this design issue was resolved in Study 2—by using discrete floors of a building rather than separate areas on the same

floor—the expected interaction was observed. In Study 2 the effects for employees' concentration levels did not reach statistical significance. Again, although concentration levels increased somewhat in the green condition, there was also a small but nonsignificant rise in concentration levels in the lean condition preventing the interaction from becoming statistically significant. Taking all findings together, we conclude that the two nonsignificant effects are not so inconsistent as to seriously invalidate the hypothesized effects. Therefore, we conclude that overall there is reasonably strong evidence in favor of the hypothesis.

Second, as already noted, the patterns observed in regard to call-center productivity (Study 2) were discrepant from those obtained on other measures. We attributed this to the ambiguous nature of the productivity measurements used by the organization in question (which valued fast responses over longer responses). We argued that such metrics are problematic in so far as they have no bearing on the quality of the conversation, the rapport developed between the engaged parties, or the financial implications of the interaction. That a company should struggle to measure productivity is not unusual (Allen, 2011; Djellal & Gallouj, 2008; Blois, 1984). Indeed, the consultancy business which hosted the productivity experiment (Study 3) was not confident that their own measurements of *face time with clients* and *billable hours worked* properly captured staff's productivity. It was mooted that these business data might, for example, reflect levels of seniority (where senior staff cherry pick—or are given—the best jobs) or the quality of the secretarial support available. As a consequence, in our final study we relied upon office-based tasks that approximated more closely to the general skills pertinent to the modern workplace (following Knight & Haslam, 2010b). Clearly, however, in future research there is a need to calibrate these measures even more closely, with a view to establishing the validity of our interpretation of the outcomes observed across the three studies here.

Third, the focus of this study was on the differences between lean space and green space. This is clearly a narrow band of potential environmental options. Nevertheless, this very narrowness can itself be taken as providing evidence of the relatively minimal changes that seem to be needed to deliver both psychological and commercial advantage. In this context, it is all the more remarkable how reluctant organizations often are to take advantage of such opportunities to improve the quality of work environments for employees (Vischer, 2005).

It follows that, as a fourth point, more research needs to be undertaken to advance upon the present work. In particular, the third study had a small sample and replication of findings across tasks and contexts would be important. In line with previous studies, there would also seem to be value in clarifying the potential for empowering workers to make decisions about the office environment and any greening initiative that is undertaken (Durmusoglu & Kulak, 2008; Elsbach, 2003; Knight & Haslam, 2010b). Finally, the present research did not include a measure of creativity. As this is something that both lean and green workspace practitioners claim to be able to enhance (Laing, Duffy, Jaunzens, & Willis, 1998; Tapping & Dunn, 2006), it would be useful to test these claims scientifically in future research. Extending the rationale of the present study, we have begun to explore these questions among various commercial organizations where preliminary data accord closely with the conclusions of the present research. Specifically, they indicate that creative decision making is more prevalent in an office space enriched with plants than in a lean alternative.

Concluding Comment

The present research makes a novel contribution to the literature on office space by directly comparing the benefits of two modern approaches with contemporary office design. One of these approaches—lean—is common, the other—enrichment—less so, especially among lower-status workers. The results demonstrate how office landscaping strategies that involve transforming a lean office into a green one contribute not only to employee welfare but also to organizational output. Lean, it appears, is meaner than green, not only because it is less pleasant but also because it is less productive.

References

Adachi, M., Rohde, C. L. E., & Kendle, A. D. (2000). Effects of floral and foliage displays on human emotions. *HortTechnology, 10,* 59–63.

Allen, T. (2011). *All in a day's work.* Salford, UK: Worktech Conference.

Appleton, J. (1975). *The experience of landscape.* London, UK: Wiley.

Baldry, C., Bain, P., & Taylor, P. (1998). "Bright satanic offices:" Intensification, control and team Taylorism. In P. Thompson & C. Warhurst (Eds.), *Workplaces of the future* (pp. 163–183). Basingstoke, UK: Macmillan.

Baldry, C., & Hallier, J. (2010). Welcome to the house of fun: Work space and social identity. *Economic and Industrial Democracy, 31,* 150–172. doi:10.1177/0143831X09351215

Balling, J. D., & Falk, J. H. (1982). Development of visual preference for natural environments. *Environment and Behavior, 14,* 5–28. doi:10.1177/0013916582141001

Barnatt, C. (1995). Office space, cyberspace, and virtual organization. *Journal of General Management, 20,* 78–91.

Bergs, J. (2002, June). *Effect of healthy workplaces on well-being and productivity of office workers.* Proceedings of International Plants for People Symposium, Floriade, Amsterdam, Netherlands.

Berman, M., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science, 19,* 1207–1212. doi:10.1111/j.1467-9280.2008.02225.x

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology, 25,* 249–259. doi:10.1016/j.jenvp

Blois, K. J. (1984). Productivity and effectiveness in service firms. *Service Industries Journal, 4,* 49–60.

Bringslimark, T., Hartig, T., & Patil, G. G. (2007). Psychological benefits of indoor plants in workplaces: Putting experimental results into context. *HortScience, 42,* 581–587.

Carrer, P., Alcini, D., Cavallo, D., Visigalli, F., Bollini, D., & Maroni, M. (1999). Home and workplace complaints and symptoms in office workers and correlation with indoor air pollution. *Indoor Air, 1,* 129–134.

Chang, C.-Y., & Chen, P.-K. (2005). Human responses to window views and indoor plants in the workplace. *HortScience, 40,* 1354–1359.

Cicchetti, D. V., & Sparrow, S. A. (1981). Developing criteria for establishing interrater reliability of specific items: Applications to assessment of adaptive behavior. *American Journal of Mental Deficiency, 86,* 127–137.

Cimprich, B. (1993). Development of an intervention to restore attention in cancer patients. *Cancer Nursing, 16,* 83–92. doi:10.1097/00002820-199304000-00001

Cimprich, B., & Ronis, D. L. (2003). An environmental intervention to restore attention in women with newly diagnosed breast cancer. *Cancer Nursing, 26,* 284–292. doi:10.1097/00002820-200308000-00005

Cohen, L. M. (2007). Bridging two streams of office design research: A comparison of design/behavior and management journal articles from 1980–2001. *Journal of Architectural and Planning Research, 24,* 289–307.

Cole, D. A., & Maxwell, S. E. (2003). Testing mediational models with longitudinal data: Questions and tips in the use of structural equation modeling. *Journal of Abnormal Psychology, 112,* 558–577. doi:10.1037/0021-843X.112.4.558

Coleman, C. K., & Mattson, R. H. (1995). Influences of foliage plants on human stress during thermal biofeedback training. *HortTechnology, 5,* 137–140.

Crampton, C. (2011, April 8). *£40,000 on pot plants? Really?* [Web log message]. Retrieved from http://www.totalpolitics.com/blog/155437/40000-on-pot-plants-really.thtml

Crompton, R., & Jones, G. (1984). *White-collar proletariat: Deskilling and gender in clerical work*. Philadelphia, PA: Temple University Press.

Dixon, M. (2009, November). *Discussion on productivity at work*. Paper presented at the meeting of Worktech Conference, London, United Kingdom.

Djellal, F., & Gallouj, F. (2008). *Measuring and improving productivity in services: Issues, strategies and challenges*. Cheltenham, UK: Edward Elgar. doi:10.4337/9781848444966

Dolan, B. (2004). *Josiah Wedgwood: Entrepreneur to the enlightenment*. London, UK: Harper Perennial.

Doxey, J. S., Waliczek, T. M., & Zajicek, J. M. (2009). The impact of interior plants in university classrooms on student course performance and on student perceptions of the course and instructor. *HortScience, 44,* 384–391.

Dravigne, A., Waliczek, T. M., Lineberger, R. D., & Zajicek, J. M. (2008). The effects of live plants and window views of green spaces on employee perceptions of job satisfaction. *HortScience, 43,* 183–187.

Duffy, F., & Hutton, L. (1998). *Architectural knowledge: The idea of a profession: The new professionalism*. New York, NY: Routledge.

Durmusoglu, M. B., & Kulak, O. (2008). A methodology for the design of office cells using axiomatic design principles. *Omega- International Journal of Management Science, 36,* 633–652. doi:10.1016/j.omega.2005.10.007

Elsbach, K. D. (2003). Relating physical environment to self-categorizations: Identity threat and affirmation in a non-territorial office space. *Administrative Science Quarterly, 48,* 622–654. doi:10.2307/3556639

Fjeld, T. (2000). The effect of interior planting on health and discomfort among workers and school children. *HortTechnology, 10,* 46–52.

Fjeld, T., Levy, F., Bonnevie, C., Sandvik, L., Veiersted, B., & Rüse, G. (1999). Foliage plants both with and without additional fluorescent light, may reduce in-door health-and discomfort complaints. *Proceedings Indoor Air, 4,* 16–21.

Fjeld, T., Veiersted, B., Sandvik, L., Riise, G., & Levy, F. (1998). The effect of indoor foliage plants on health and discomfort symptoms among office workers. *Indoor and Built Environment, 7,* 204–209. doi:10.1177/1420326X9800700404

George, M. L. (2003). *Lean six sigma for service: How to use lean speed and six sigma quality to improve services and transactions*. New York, NY: McGraw-Hill.

Haberkorn, G. (2005). Improving flow in an office setting. In Productivity Press Development Team (Ed.), *The lean office: Collected practices and cases* (pp. 95–104). New York, NY: Productivity Press.

Handy, C. (1990). *The age of unreason*. Boston, MA: Harvard Business School Press.

Hansard. (2011). *Departmental plants (column 1277W)*. London, UK: Author.

Harris, C., & Harris, R. (2006). *Developing a lean workforce: A guide for human resources, plant managers, and lean coordinators*. New York, NY: Productivity Press.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Garling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology, 23,* 109–123. doi:10.1016/S0272-4944(02)00109-3

Haslam, S. A. (2004). *Psychology in organizations. The social identity approach*. London, UK: Sage.

Haslam, S. A., & Knight, C. P. (2006). *Your place or mine?* BBC News Web site. Retrieved from http://news.bbc.co.uk/1/hi/magazine/6155438.stm

Haslam, S. A., & Knight, C. (2010). Cubicle, sweet cubicle: Why some office spaces alienate workers, while others make them happier and more efficient. *Scientific American Mind, 21,* 30–35. doi:10.1038/scientificamericanmind0910-30

Hirano, H. (1996). *5 pillars of the visual workplace: The sourcebook for 5S implementation*. New York, NY: Productivity Press.

Hox, J. (2002). *Multilevel analysis: Techniques and applications*. Mahwah, NJ: Erlbaum.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6,* 1–55. doi:10.1080/10705519909540118

Hyer, N. L., & Wemmerlov, U. (2002). The office that lean built. *IEE Solutions, 34,* 37–43.

Kahn, W. A. (1990). Psychological conditions of personal engagement and disengagement at work. *Academy of Management Journal, 33,* 692–724. doi:10.2307/256287

Kaplan, R., Kaplan, S., & Brown, T. (1989). Environmental preference: A comparison of four domains of predictors. *Environment & Behavior, 21,* 509–530. doi:10.1177/0013916589215001

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 15,* 169–182. doi:10.1016/0272-4944(95)90001-2

Katz, D., & Kahn, R. L. (1966). *The social psychology of organizations*. New York, NY: Wiley.

Khan, A. R., Younis, A., Riaz, A., & Abbas, M. M. (2005). Effect of interior plantscaping on indoor academic environment. *Journal of Agriculture Research, 43,* 235–242.

Kim, E., & Mattson, R. H. (2002). Stress recovery effects of viewing red-flowering geraniums. *Journal of Therapeutic Horticulture, 13,* 4–12.

Knight, C., & Haslam, S. A. (2010a). Your place or mine? Organizational identification and comfort as mediators of relationships between the managerial control of workspace and employees' satisfaction and well-being. *British Journal of Management, 21,* 717–735. doi:10.1111/j.1467-8551.2009.00683.x

Knight, C., & Haslam, S. A. (2010b). The relative merits of lean, enriched, and empowered offices: An experimental examination of the impact of workspace management. *Journal of Experimental Psychology: Applied, 16,* 158–172. doi:10.1037/a0019292

Laing, A., Duffy, F., Jaunzens, D., & Willis, S. (1998). *New environments for working*. London, UK: Construct Research Communications. doi:10.4324/9780203223109

Larsen, L., Adams, J., Deal, B., Kweon, B. S., & Tyler, E. (1998). Plants in the workplace: The effects of plant density on productivity, attitudes, and perceptions. *Environment and Behavior, 30,* 261–281. doi:10.1177/001391659803000301

Laumann, K., Gärling, T., & Stormark, K. M. (2003). Selective attention and heart rate responses to natural and urban environments. *Journal of Environmental Psychology, 23,* 125–134. doi:10.1016/S0272-4944(02)00110-X

Lewin, K. (1956). Studies in group decision. In D. Cartwright & A. Zander (Eds.), *Group dynamics: Research and theory* (2nd ed., pp. 287–301). Evanston, IL: Row Peterson.

Liu, M., Kim, E., & Mattson, R. H. (2003). Physiological and emotional influences of cut flower arrangement and lavender fragrance on university students. *Journal of Therapeutic Horticulture, 14,* 18–27.

Lohr, V. I., Pearson-Mims, C. H., & Goodwin, G. K. (1996). Interior plants may improve worker productivity and reduce stress in a windowless environment. *Journal of Environmental Horticulture, 14,* 97–100.

Mann, D. (2010). *Creating a lean culture: Tools to sustain lean conversions*. New York, NY: Productivity Press. doi:10.1201/EBK1439811412

Markovitz, D. (2012). *A factory of one: Applying lean principles to banish waste and improve your personal performance*. Boca Raton, FL: CRC Press.

Millward, L. J., Haslam, S. A., & Postmes, T. (2007). Putting employees in their place: The impact of hot-desking on organizational and team identification. *Organization Science, 18,* 547–559. doi:10.1287/orsc.1070.0265

Mølhave, L., & Krzyzanowski, M. (2003). The right to healthy indoor air: Status by 2002. *Indoor Air, 13,* 50–53. doi:10.1034/j.1600-0668.13.s.6.7.x

Morris, N. (2011, April 8). Coalition ministers spend £40,000 on potted plants. *The Independent*. Retrieved from http://www.independent.co.uk

Myerson, J. (2007). Focus on: Office design. *Architects' Journal Specification, 1,* 23–28.

Orians, G. H. (1980). Habitat selection: General theory and applications to human behaviour. In J. Lockard (Ed.), *The evolution of human social behaviour* (pp. 49–66). Chicago, IL: Elsevier.

Orians, G. H., & Heerwagen, J. H. (1992). Evolved responses to landscapes. In J. H. Barkow, L. E. Cosmides, & J. E. Tooby (Eds.), *The Adapted mind: Evolutionary psychology and the generation of culture* (pp. 555–579). Oxford, UK: Oxford University Press.

Orwell, R. L., Wood, R. L., Tarran, J., Torpy, F., & Burchett, M. D. (2004). Removal of benzene by the indoor plant/ substrate microcosm and implications for air quality. *Water, Air, and Soil Pollution, 157,* 193–207. doi:10.1023/B:WATE.0000038896.55713.5b

Ottosson, J., & Grahn, P. (2005). A comparison of leisure time spent in a garden with leisure time spent indoors: On measures of restoration in residents in geriatric care. *Landscape Research, 30,* 23–55. doi:10.1080/0142639042000324758

Parker, D. C. (1992). The corporate garden. In D. Relf (Ed.), *The role of horticulture in human well-being and social development* (pp. 28–32). Portland, OR: Timber Press.

Peters, T., & Waterman, R. H. (2004). *In search of excellence*. London, UK: Profile Books.

Saner, E. (2012, April 3). *Pot plants in the office: Good or bad?* [Web log message]. Retrieved from http://www.guardian.co.uk/lifeandstyle/shortcuts/2012/apr/03/pot-plants-in-the-office

Sayer, J. N., & Williams, B. (2006). *Lean for dummies*. Hoboken, NJ: Wiley.

Selig, J. P., & Preacher, K. J. (2009). Mediation models for longitudinal data in developmental research. *Research in Human Development, 6,* 144–164. doi:10.1080/15427600902911247

Seppänen, O., Fisk, W. J., & Lei, Q. H. (2006). Ventilation and performance in office work. *Indoor Air, 16,* 28–36. doi:10.1111/j.1600-0668.2005.00394.x

Shaughnessy, R. J., Haverinen-Shaughnessy, U., Nevalainen, A., & Moschandreas, D. (2006). The effects of classroom air temperature and outdoor air supply rate on the performance of school work by children. *Indoor Air, 16,* 465–468. doi:10.1111/j.1600-0668.2006.00440.x

Shibata, S., & Suzuki, N. (2001). Effects of indoor foliage plants on subjects' recovery from mental fatigue. *North American Journal of Psychology, 3,* 385–396.

Shibata, S., & Suzuki, N. (2002). Effects of the foliage plant on task performance and mood. *Journal of Environmental Psychology, 22,* 265–272. doi:10.1006/jevp.2002.0232

Shibata, S., & Suzuki, N. (2004). Effects of an indoor plant on creative task performance and mood. *Scandinavian Journal of Psychology, 45,* 373–381. doi:10.1111/j.1467-9450.2004.00419.x

Shoemaker, C. A., Randall, K., Relf, P. D., & Geller, E. S. (1992). Relationships between plants, behavior, and attitudes in an office environment. *HortTechnology, 2,* 205–206.

Skinner, C. (2005). First steps to making your office lean. In Productivity Press Development Team (Ed.), *The lean office: Collected practices and cases* (pp. 65–69). New York, NY: Productivity Press.

Snijders, T. (1996). Analysis of longitudinal data using the hierarchical linear model. *Quality & Quantity, 30,* 405–426. doi:10.1007/BF00170145

Sundstrom, E., & Sundstrom, M. G. (1986). *Work places: The psychology of the physical environment in offices and factories (environment and behavior)*. Cambridge, UK: Cambridge University Press.

Tapping, D., & Dunn, A. (2006). *Lean office demystified*. Chelsea, MI: MCS Media.

Tarran, J., Orwell, R. L., Burchett, M. D., Wood, R. L., & Torpy, F. (2002). *Quantification of the capacity of indoor plants to remove volatile organic compounds under flow-through conditions*. Sydney, NSW, Australia: Horticulture Australia.

Tarran, J., Torpy, F., & Burchett, M. (2007, October). *Use of living pot plants to cleanse indoor air: A research review*. Proceedings of sixth international conference on Indoor Air Quality, Ventilation & Energy Conservation in Buildings—Sustainable Built Environment, Sendai, Japan.

Taylor, F. W. (1911). *The principles of scientific management*. New York, NY: Harper & Brothers.

Tennessen, C. M., & Cimprich, B. (1995). Views to nature: Effects on attention. *Journal of Environmental Psychology, 15,* 77–85. doi:10.1016/0272-4944(95)90016-0

Thompson, J. (2000). *Lean production for the office: Common sense ideas to help your office continuously improve*. Toronto, Canada: Productive.

Ulrich, R. S. (1979). Visual landscapes and psychological well-being. *Landscape Research, 4,* 17–23. doi:10.1080/01426397908705892

Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. F. Wohlwill (Eds.), *Human behavior and the natural environment: Advances in theory and research* (Vol. 6, pp. 85–125). New York, NY: Plenum Press. doi:10.1007/978-1-4613-3539-9_4

Ulrich, R. S. (1986). Human responses to vegetation and landscapes. *Landscape and Urban Planning, 13,* 29–44. doi:10.1016/0169-2046(86)90005-8

Ulrich, R. S., & Simons, R. F. (1986). *Recovery from stress during exposure to everyday outdoor environments*. In J. Wineman, R. Barnes, & C. Zimring (Eds.), The costs of not knowing (pp. 115–122). Washington, DC: Proceedings of 17th Annual Conference of the Environmental Research and Design Association.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11,* 201–230. doi:10.1016/S0272-4944(05)80184-7

Vischer, J. C. (2005). *Space meets status.* Abingdon, UK: Routledge.

White, M. P., Alcock, I., Wheeler, B. W., & Depledge, M. H. (2013). Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. *Psychological Science, 24,* 920–928. doi:10.1177/0956797612464659

Wiers-Jenssen, J., Stensaker, B. R., & Grøgaard, J. B. (2002). Student satisfaction: Towards an empirical deconstruction of the concept. *Quality in Higher Education, 8,* 183–195. doi:10.1080/13538320220000004377

Wood, R. A., Burchett, M. D., Alquezar, R., Orwell, R., Tarran, J., & Torpy, F. (2006). The potted-plant microcosm substantially reduces indoor air VOC pollution: I. Office field-study. *Water, Air, and Soil Pollution, 175*, 163–180. doi:10.1007/s11270-006-9124-z

Wood, R. A., Orwell, R. L., Tarran, J., Torpy, F., & Burchett, M. D. (2002). Potted-plant/growth media interactions and capacities for removal of volatiles from indoor air. *Journal of Horticultural Science and Biotechnology, 77*, 120–129.

Worthington, J. (2006). *Reinventing the workplace*. Oxford, UK: Elsevier.

Zeisel, J. (2006). *Inquiry by design*. New York, NY: Newton.

Zelinsky, M. (2006). *The inspired workspace: Design for creativity and productivity*. Gloucester, MA: Rockport.

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