



OPEN Explaining the influence of biophilic design on employee well-being

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Biophilic workplace design has been proposed as an effective strategy to increase employee well-being in open-plan offices. To expand our understanding of why and for whom indoor nature exposure increases well-being, the aim of this study was to evaluate vigor as a mediator and to examine whether nature relatedness is a direct antecedent of nature exposure or a moderator of the relationship between exposure to nature and vigor. Based on longitudinal data obtained from a two-wave panel design with white-collar workers in open-plan offices (Study 1, $n = 345$; Study 2, $n = 291$), using a rival model strategy and two dependent variables, i.e., job well-being and overall well-being, this study revealed that nature relatedness is a direct antecedent of nature exposure and that vigor mediates the relationship between nature exposure and the examined outcomes. These results indicate that although natural exposure increases employee well-being, the effects are indirectly driven by employees' connection with nature. These findings have implications for the implementation of biophilic workplace design.

Employees in open-plan offices have been found to report more distractions, uncooperative behaviors, negative relationships, and distrust¹. Moreover, extant evidence suggests that shared offices have reduced the quality of the indoor environment, which decreases employee well-being^{2,3}. While ergonomics has long been dedicated to studying how indoor environmental quality affects employee well-being and work performance⁴, more recently, following calls for nature as a new paradigm for ergonomics³, attention has been given to greening workspaces or biophilic design^{5,6} as a design strategy suitable for enhancing the well-being of employees working in open plan offices⁷.

Biophilic design integrates nature into workspaces to enable employees' "meaningful engagement with nature⁸: [232]". Employees' self-reported counts of plants or natural elements in view and/or green window views positively correlate with productivity⁹, job satisfaction^{10–12} and job engagement¹³. Similarly, indoor nature exposure (NE) is correlated with employee well-being^{10–12,14,15}. Nonetheless, some of these studies report small effects⁹, nonsignificant effects on long-term well-being¹⁶ and significant variability in NE among workers^{12,17}.

To better explain the relationship between nature exposure and well-being, this study first examined the psychological mediating mechanisms involved in this relationship; this is in response to past calls for more research into the mechanisms that explicate the relationship between workplace design and well-being¹⁸ and between biophilic design and well-being¹⁹. Second, we differentiated between the immediate and work-specific effects and the longer-term effects on well-being. While the majority of the research has examined short-term and work-specific effects, a study testing effects on long-term well-being found no significant results¹⁶. Examining effects in the short- and long-term can also help clarify the relationship between NE and well-being. Finally, we assessed the influence of employee traits, specifically employees' preferences for nature contact. As preferences for NE vary among individuals, the research shows that biophilic design may not equally benefit all individuals^{20–22}, an issue that has prompted calls for more research into the employee traits that may affect the examined relationship²³.

More specifically, the study examined the mediating effect of vigor. Vigor, like other related constructs such as vitality, is often cited in the literature as a "subjective feeling of energy and aliveness²⁴: [437]". In the human resource literature, vigor has been conceptualized as a component of work engagement, alongside dedication and absorption²⁵, and is defined as "high energy and mental resilience while working, a willingness to invest effort in one's work, and persistence even in the face of difficulties²⁶: [245]".

Increased vigor as a result of NE is consistent with both attention-restoration theory (ART)¹¹ and stress reduction theory (SRT)²⁷ since, according to these theories, NE increases cognitive and emotional energy, respectively⁸. Because NE increases positive emotions²⁸ and reduces mental fatigue, it is deemed to increase vigor^{13,29}. Similarly, the positive relationship between vigor and job well-being is well established in the literature^{30–32}. Nevertheless, the mediating role of vigor has been overlooked in previous studies of NE and job

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well-being. In the present study, as vigor represents energy that can be harnessed later to increase the amount of work done during the day, it is expected that greater vigor will lead to greater same-day job well-being. Moreover, following past studies^{33,34}, we expect cumulative effects of vigor in the long term and thus hypothesize that increased vigor will lead to greater well-being³⁵.

Additionally, this paper examined the role of employees' nature relatedness (NR) as a trait that can explain the different reactions of employees to NE⁷. NR, which "refers to one's subjective sense of connection with the natural world^{36, 37}", has been found to explain the observed variation in the perceived restorativeness of nature^{8,37,38}. Individuals with higher levels of NR view natural environments as more attractive and fascinating³⁹, attribute a greater restorative ability to natural environments⁴⁰, and tend to seek experiences in nature to a greater extent³. In the context of the workplace, NR was only measured by⁵, who reported a correlation among satisfaction with biophilic design, NR and self-reported health. This correlation provides evidence of the influence of NR but does not allow disambiguation of the causal role of NR. Specifically, two competing explanations have been proposed: (1) NR as an antecedent of NE and (2) NR as a moderator of the relationship between NE and vigor.

On the one hand, NR as an antecedent of NE is plausible, drawing from identity-salience motivation theory^{41,42}, which shows that individuals engage in practices and allocate attention to stimuli in self-relevant ways. Thus, we can expect that workers with higher NR are more likely to bring natural elements into their workspace, or that even when these natural elements are built into the workspace design, they will be more likely to pay attention to them during the workday and be more likely to remember and report them, given that these natural elements are more salient to them³⁹. Furthermore, employees with high NR benefit from the restorative effects of NE and experience greater vigor^{6,43}. In contrast, individuals with low NR do not pay much attention to indoor natural elements, report a fewer number of plants in view, and experience the reinvigorating effects of NE to a lesser extent. This argument is consistent with other researchers who claim that NE per se might not elicit positive effects, but rather, it is individuals with a sense of connection to nature who benefit from the restorative potential of NR^{44,45}. Moreover, studies examining the effects of NR have shown that it leads to similar outcomes as those associated with NE^{46–48}. Specifically, meta-analytical evidence shows that those with higher levels of NR tend to have higher levels of vigor, positive affect, and life satisfaction than do those who are less connected to nature^{45,49}. If NR and NE have both been found to be antecedents of the same outcomes, given that NR is a dispositional trait of workers, it is plausible to expect that NR is positively associated with NE, thus NR has an indirect effect on observed outcomes.

On the other hand, research on the restorative potential of landscapes has suggested a moderating role for NR, i.e., NR interacts with NE to explain the dependent variables³. Unlike the previous explanation, this perspective accepts that NE would correlate with increased vigor for all workers but that the strength of the effects would be greater for those with greater NR^{6,43}.

To disambiguate the causal relationship between NR and NE on employee well-being, we tested and compared two rival models: NR as an antecedent of NE and NR as a moderator of the relationship between NE and vigor. A two-wave panel study with service workers in open-plan offices that employs a rival model strategy and examines two dependent variables, i.e., same-day job well-being and well-being three months later, revealed that the amount of nature to which workers are exposed correlates with the well-being of employees in open-plan offices. This study also showed that vigor mediates this effect. Finally, the study offers empirical evidence that, although NE correlates with well-being, NR appears to act as an antecedent of NE, thus indirectly affecting vigor and well-being.

Method

Data were collected via an online questionnaire administered by a panel of a commercial marketing research company. The questionnaire was administered following the guidelines of the Declaration of Helsinki for nonexperimental studies and in compliance with relevant regulations and guidelines. Because no personal data were collected, the study involved no risks for participants, vulnerable populations were not targeted, all participants provided informed consent, and ethics approval was waived by the ethics committee of Comillas University.

The target population was white-collar workers working in open offices in Spain. Given that the type of office influences employees' well-being², a focus on open-office workers ensured homogeneity in the sample and isolated other possible confounding factors. A priori power analysis for multiple linear regression with a small to medium effect size (0.08), power of 0.95, and alpha of 0.05 with seven predictors suggested a sample size of 165. Accordingly, we oversampled at T1 to ensure that we would reach the sample size of 165 at T2.

A total of 563 individuals completed the questionnaire at time 1 (T1). Given that the variables in Study 1 were used to measure the effects during a workday, the participants were asked about the percentage of working hours already completed when they responded to the survey. For Study 1, only those who completed at least 50% of the workday were included in the study²³. With this exclusion, the valid sample for Study 1 (using all variables at T1) consisted of 345 individuals. A total of 54.2% were female; $M_{\text{age}} = 40.42$ years ($SD = 11.58$); 70.7% were married or lived with their partners; 78% had studied at a university; and 17.7% held managerial positions in the firms.

Three months later (T2), all the respondents were contacted again and asked to complete a measure of well-being. Given that the hypothesized effects of NE on well-being are thought to be based on repeated exposure to nature in the workplace, we included all respondents at T1 (both those who had and had not completed at least 50% of the workday) who also responded to the questionnaire at T2. With this procedure, Study 2 (which used variables at T1 and T2) was based on a valid sample of 291 individuals. A total of 60.49% were female; $M_{\text{age}} = 41.26$ years ($SD = 10.35$); 72.16% were married or lived with their partners; 75.60% had studied at a university; and 16.84% held managerial positions in the firms. To minimize the potential effects of common-method bias, all scales were randomized, and an attention check was included⁵⁰. Harman's one-factor test (an unrotated factor analysis on all items used in the model), which was conducted on the correlational data used for

Study 1, revealed that the variance explained by the first factor was well under half of the total variance (38.1%); thus, common-method bias is unlikely to be a risk. Since Study 2 was based on data gathered at two points in time, common-method bias is unlikely to be a risk.

Indoor Nature Exposure was measured through an index created following the Nature Contact Questionnaire¹⁴. This measure of the amount of nature that employees can see from their workstations has been widely used in past studies (e.g.^{9,10,17,51}); it was calculated as the sum of the following items: (1) number of live plants or flower arrangements ($M_{S1} = 1.75$; $SD_{S1} = 1.67$; $M_{S2} = 1.63$; $SD_{S2} = 1.63$); (2) number of artificial plants or artificial flowers ($M_{S1} = 0.94$; $SD_{S1} = 1.38$; $M_{S2} = 0.94$; $SD_{S2} = 1.38$); (3) number of windows providing views of the outside landscape ($M_{S1} = 2.68$; $SD_{S1} = 1.41$; $M_{S2} = 2.59$; $SD_{S2} = 1.36$); (4) number of drawings or posters that represent scenes of nature or animals ($M_{S1} = 1.55$; $SD_{S1} = 1.55$; $M_{S2} = 1.38$; $SD_{S2} = 1.45$); and (5) number of photographs of scenes of nature or animals ($M_{S1} = 1.15$; $SD_{S1} = 1.48$; $M_{S2} = 1.04$; $SD_{S2} = 1.42$). For each item, the respondents indicated the number of natural elements that could be seen from their workplace while working, i.e., ranging from 0 to 5 or more).

Nature Relatedness was measured using the short version of the Nature Relatedness Questionnaire (6-item, 7-point Likert scale)⁵². Sample items included “My ideal vacation spot would be a remote, wilderness area” or “My relationship to nature is an important part of who I am”. This brief scale has exhibited good reliability and validity among Spanish populations⁵³ ($\alpha_{S1} = 0.90$; $\alpha_{S2} = 0.90$).

Vigor was measured using 4 items from the vigor scale of the Utrecht Work Engagement Scale²⁵, which was validated in Spanish⁵⁴. Sample items include “I feel like I have a lot of energy at work” and “I have been able to work for long periods of time” ($\alpha_{S1} = 0.85$; $\alpha_{S2} = 0.86$). The responses to these items were obtained via a seven-point Likert scale ranging from 1 = strongly disagree to 7 = strongly agree.

Job-specific Well-being was measured at T1 via five items that assessed job satisfaction, a widely agreed-upon measure of job well-being⁵⁵. Two items were taken from the⁵⁶ productivity scale, which has been previously used in similar studies (e.g.⁹), and three items were taken from the⁵⁷ job satisfaction scale, which has been previously validated in Spanish by⁵⁸. Sample items are “I am satisfied with the amount of work I have done today” and “I am satisfied with my work today” ($\alpha = 0.89$). The responses to these items were obtained using a seven-point Likert scale ranging from 1 = strongly disagree to 7 = strongly agree.

Well-being was measured at T2 with seven items from the Oxford Happiness Questionnaire⁵⁹, whose psychometric properties have been validated among Spanish samples⁶⁰. Sample items included “I find beauty in some things” and “I am well satisfied about everything in my life”. The responses to these items were obtained using a seven-point Likert scale ranging from 1 = strongly disagree to 6 = strongly agree ($\alpha = 0.87$).

All scales were used with permission from the authors and/or in compliance with the copyright licence of the journals in which they were published.

Control Variables: Based on previous studies on the variables that affect job satisfaction, we included as control variables gender⁶¹, age⁶², marital status⁶³ and job position, all of which were measured at T1.

Different analyses were conducted to test our hypotheses. In Study 1, we examined the relationships among NE, NR, vigor and job-specific well-being (JWB). Accordingly, all the variables in this study were measured at T1. Following a rival model strategy, we calculated separate models. Model 1 was the baseline model, which tested the relationships among NE, vigor and job well-being. Then, Models 2 and 3 were generated by incrementing Model 1 through competing ways. For example, Model 2 tested NR as an antecedent of NE, and Model 3 tested whether NR moderated the relationship between NE and vigor. The same strategy was followed in Study 2, albeit the state construct of job well-being was replaced by well-being. Thus, in Study 2, all the variables were measured at T1, except for well-being, which was measured at T2.

To estimate the models, we employed SEM analysis, including control measures of age, gender, marital status, and position. Accordingly, we initially checked the measurement model to ensure the goodness of fit of the employed scales. We then ran the structural models to test the hypotheses. Additionally, to check for the mediating role of vigor, we analysed the indirect effects of NE and NR on job well-being and the indirect effects of NE and NR on well-being. To ensure significance, we conducted bootstrapping via the bias-corrected percentile method based on a bootstrap sample of 200.

Results

Study 1

The mean value for NE is 7.94, indicating that workers in our sample have, on average, between 7 and 8 nature items visible from their workplace (Table 1). With respect to the different elements of NE considered, window views were the most frequently reported element ($M = 2.68$; $SD = 1.41$), followed by natural plants ($M = 1.75$; $SD = 1.67$). The item least frequently reported was artificial plants ($M = 0.94$; $SD = 1.38$).

Before the measurement model was tested, several confirmatory factor analyses (CFAs) were conducted on the data collected in Study 1. The corresponding measurement model was compared with a series of alternative nested models in which different factors were loaded on a single construct. The final measurement model significantly fit the data better than did the alternative models, thereby confirming construct discriminant validity (Table 2). The standardized regression weights (SRW) were significant ($p < 0.01$), as all of them were greater than 0.6, and the AVE and composite reliability of the NR (0.63 and 0.91, respectively), vigor (0.60 and 0.86, respectively) and JWB (0.63 and 0.90, respectively) scales were good, supporting the convergent validity of the scales. In Model 1, the variables NE, vigor, JWB, and control variables (age, gender, marital situation, and position) were included. As none of the control variables were statistically significant, we reran the model without control variables to obtain a more parsimonious model. The findings show that vigor fully mediated the relationship between NE and job well-being (Table 3, Fig. 1). Accordingly, the indirect effect of NE on job well-being was statistically significant and positive. These results support the mediating role of vigor.

Correlations								
Variable	Female	Age	Married	Managerial	NR	NE	Vigor	JWB
Female								
Age	0.054							
Married	0.048	0.053						
Managerial	−0.184**	0.005	0.098					
NR	0.117*	−0.014	0.093	0.090				
NE	0.036	−0.158**	0.033	0.126*	0.116*			
Vigor	−0.005	−0.057	0.045	0.122*	0.255**	0.185**		
WB	0.035	0.043	0.113	0.118*	0.335**	0.058	0.443**	
Mean	0.54	40.42	0.71	0.18	4.44	7.94	4.80	5.15
Std. Dev	0.50	11.58	0.46	0.38	1.02	5.26	1.23	1.16

Table 1. Study 1 descriptive statistics. *, ** Statistically significant at the 5 and 1% correspondingly.

Nested model	Chi	df	Chi/df	GFI	IFI	TLI	RMSEA	Description	Model fit difference p-val
STUDY 1									
N1	1490.38	90	16.56	0.532	0.573	0.500	0.213	1-construct model: (NR + Vigor + JWB)	<0.001
N2	366.966	89	4.123	0.870	0.915	0.900	0.095	2-construct model: (NR)–(Vigor + JWB)	<0.001
N3	261.450	87	3.005	0.904	0.947	0.936	0.076	3-construct model: (NR)–(Vigor)–(JWB)	Measurement model (reference for comparison)
STUDY 2									
N1	1228.17	118	10.408	0.554	0.589	0.523	0.18	1-construct model: (NR + Vigor + WB)	<0.001
N2	569.162	117	4.856	0.762	0.883	0.804	0.145	2-construct model: (NR)–(Vigor + WB)	<0.001
N3	240.510	115	2.091	0.908	0.954	0.945	0.061	3-construct model: (NR)–(Vigor)–(WB)	Measurement model (reference for comparison)

Table 2. Study 1 and Study 2 discriminant validity (nested model comparison).

STUDY 1						
			Model 1	Model 2	Model 3	
Standardized direct effects						
Vigor	<–	NE	0.135 (0.019)	0.133 (0.021)	0.081 (0.167)	
JWB	<–	NE	0.069 (0.079)	0.032 (0.415)	0.030 (0.429)	
JWB	<–	Vigor	0.843 (<0.001)	0.837 (<0.001)	0.841 (<0.001)	
NE	<–	NR		0.202 (<0.001)		
Vigor	<–	NR*NE			−0.006 (0.923)	
Vigor	<–	NR			0.265 (<0.001)	
Standardized indirect effects						
JWB	<–	NE	0.114 (0.017)	0.111 (0.015)	0.068 (0.076)	
JWB	<–	NR		0.027 (0.009)	0.223 (0.012)	
Vigor	<–	NR		0.029 (0.007)		

Table 3. Study 1 standardized estimates (p values in brackets).

In Model 2, we added NR as an antecedent of NE. All the relationships were statistically significant and in the expected direction, except for the direct relationship between NE and job well-being, which was fully mediated by vigor, and consistent with Model 1. Thus, the findings of Model 2 support the antecedent role of NR.

Model 3 tested the moderating effects of NR on the relationship between NE and vigor. Therefore, we incremented Model 1 by including the corresponding interaction term between NR and NE. To capture this interaction effect separately from the sole effect of NR, vigor was also controlled by NR. To limit any effect of collinearity, interaction terms were computed by multiplying the standard scores of the corresponding variables⁶⁴. The results revealed that the only significant relationships were the path from NR to vigor and the direct relationship between vigor and job well-being. The relationship between NE and job well-being was fully mediated by vigor, and the interaction effect of NR on vigor was not statistically significant. Consequently, our results do not support the moderating role of NR in the relationship between NE and vigor. Details for the models and goodness of fit values are presented in Table 4.

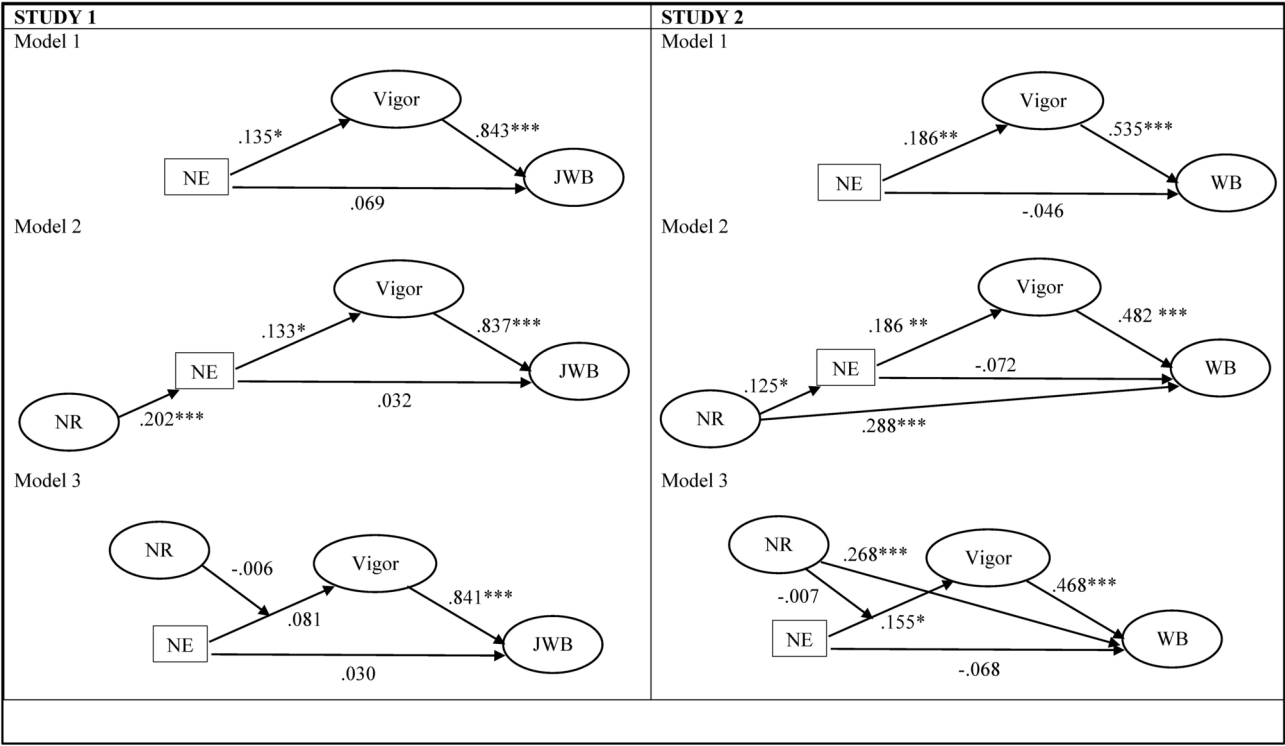


Fig. 1. Results of models in Study 1 and Study 2.

Model	Chi	df	Chi/df	GFI	IFI	TLI	RMSEA
STUDY 1							
Model 1	145.636	32	4.551	0.921	0.944	0.920	0.102
Model 2	320.933	101	3.178	0.888	0.934	0.921	0.080
Model 3	318.835	113	2.822	0.895	0.939	0.926	0.073
STUDY 2							
Model 1	110.996	51	2.176	0.935	0.961	0.950	0.064
Model 2	290.405	130	2.234	0.895	0.941	0.930	0.065
Model 3	301.621	144	2.095	0.896	0.943	0.932	0.061

Table 4. Study 1 and Study 2 goodness of fit measures.

Study 2

Attrition bias for Study 2 was assessed via ANOVA. No significant differences were found between the drop-out and follow-up groups except in terms of age ($p < 0.01$) and gender ($p < 0.01$). These variables were not significant in the models. We also checked for similarity between the samples for Study 1 and Study 2 and found no significant differences between the two samples. The correlations for the variables in Study 2 are presented in Table 5.

Before the measurement model was tested, several confirmatory factor analyses (CFAs) were conducted on the data. The corresponding measurement model was compared with a series of alternative nested models in which different factors were loaded on a single construct. The final measurement model significantly fit the data better than did the alternative models, confirming construct discriminant validity (Table 2). The standardized regression weights (SRW) were significant ($p < 0.01$), with all being greater than 0.6, and the AVE and composite reliability of the NR (0.62 and 0.91, respectively), vigor (0.61 and 0.86, respectively) and WB (0.48 and 0.87, respectively) scales were adequate, supporting the convergent validity of the scales. The measurement models yielded a good fit ($\chi^2 = 240, 5100$; $df = 115$; $GFI = 0.908$; $IFI = 0.954$; $TLI = 0.945$; $RMSEA = 0.061$).

In Study 2, we followed the same strategy as in Study 1. The results of Model 1 (Table 6, Fig. 1) show the full mediation of vigor between NE and well-being. In Model 2, NR was added to Model 1 as an antecedent to NE. Additionally, as the effect of NR on well-being is well established in the literature³, we included the link between NR and well-being to control for this effect. The findings exhibit significant and positive relationships between NR and WB and between NR and NE, offering further support for the role of NR as an antecedent of NE.

Correlations								
Variable	Female	Age	Married	Managerial	NR	NE	Vigor	JWB
Female								
Age	− 0.170**							
Married	− 0.032	0.006						
Managerial	− 0.162**	0.054	0.095					
NR	0.117*	− 0.014	0.093	0.090				
NE	0.036	− 0.158**	0.033	0.126*	0.116*			
Vigor	− 0.005	− 0.057	0.045	0.122*	0.255**	0.185**		
WB	0.035	0.043	0.113	0.118*	0.335**	0.058	0.443**	
Mean	0.60	41.26	0.72	0.17	4.49	7.59	4.81	4.65
Std. Dev	0.49	10.35	0.45	0.37	0.97	5.06	1.21	0.83

Table 5. Study 2 descriptive statistics. *, ** Statistically significant at the 5 and 1% correspondingly.

STUDY 2					
			Model 1	Model 2	Model 3
Standardized direct effects					
Vigor	< −	NE	0.186 (0.003)	0.186 (0.003)	0.155 (0.013)
NE	< −	NR		0.125 (0.042)	
Vigor	< −	NR*NE			− 0.007 (0.906)
Vigor	< −	NR			0.256 (< 0.001)
WB	< −	NE	− 0.046 (0.427)	− 0.072 (0.212)	− 0.068 (0.224)
WB	< −	Vigor	0.535 (< 0.001)	0.482 (< 0.001)	0.468 (< 0.001)
WB	< −	NR		0.288 (< 0.001)	0.262 (< 0.001)
Standardized indirect effects					
WB	< −	NE	0.114 (0.012)	0.090 (0.011)	0.073 (0.012)
WB	< −	NR		0.002 (0.674)	0.120 (0.009)
Vigor	< −	NR		0.023 (0.040)	

Table 6. Study 2 standardized estimates (p values in brackets).

Model 3 tested the moderating effects of NR on the relationship between NE and vigor. Therefore, we incorporated Model 1 by including the corresponding interaction term between NR and NE. To capture this interaction effect separately from the sole effect of NR, vigor was also controlled by NR. To limit any effect of collinearity, interaction terms were computed by multiplying the standard scores of the corresponding variables⁶⁴. Consistent with Model 2 and Study 1, the relationships were statistically significant and with the expected sign, except for the interaction effects between NR and NE on vigor and the relationships between NE and well-being, whose effect was fully captured by NR. The goodness of fit indicators for the three models are shown in Table 4.

Discussion

The aim of this study was to clarify the mixed and conflicting findings of past research regarding the relationship between biophilic design and employee well-being. Specifically, focusing on open-plan offices, the study tests whether the amount of nature that employees are exposed to correlates with short-term job-specific and long-term well-being, tests the mediating role of vigor and examines whether nature relatedness modulates the effects on the two dependent variables. Drawing from identity-based motivational theory^{41,42} and studies on the interaction effects of personal and environmental characteristics on nature restorativeness (e.g.^{39,40,65,66}), in two separate studies, the results of the study show the mediating role of vigor in the relationship between NE and the two dependent variables. We also find that NR is an antecedent of the number of reported natural items, indicating that NR indirectly drives the effects on vigor and indirectly on employee well-being. The study does not support the moderating role of NR in the relationship between NE and vigor.

This study has two implications for workspace design practice and research. First, this work offers support for biophilic design as a design strategy that enhances employee well-being in open-plan offices. The findings show that the amount of nature in view of workstations positively correlates with the well-being of workers.

Second, these effects are driven by a person-related trait, i.e., nature relatedness. Employees with a greater affiliation with nature experience greater vigor, which increases their well-being; this is consistent with identity-salience motivation theory, suggesting that employees high in this trait will allocate more attention to natural elements such as plants and experience more of the vitalizing effect of NE. This finding has two implications. First, office managers could segment their employees according to this trait and allocate workstations of greater

nature in view of those employees who are higher in NR. Second, future studies should control for dispositional NR, as this may explain the mixed evidence found^{3,67}. This control may be even more necessary in correlational studies because such studies are based on self-reported counts of indoor natural elements. These counts may correlate with workers' preferences and traits that must be controlled for, as they may contribute to explaining the observed effects.

To our knowledge, this is the first study that has offered evidence of NR as an antecedent of NE and the main driver of the observed outcomes. Studies in other domains have shown that the effects of exposure to nature on positive psychological outcomes are not moderated by attitudes towards nature⁶⁷, thus indicating that the positive effects of NE similarly drive restorative change and mood enhancement, regardless of the level of connection to nature. Nonetheless, they interpreted their results with caution given that their sample comprised park walkers with high and homogenous levels of natural connectedness. Hence, interpreting this study from our findings, we claim that it is plausible that those with high levels of natural connectedness self-selected to participate in the study; this leads to uncertainty regarding whether their dispositional NR or exposure to nature produced the observed results. Given that NR was not tested as an antecedent of the examined outcomes, such a relationship cannot be disambiguated.

This study has several limitations. We have limited the study to indoor NEs, studying the aggregated influence of direct, indirect, and representational exposure⁸. Future work could examine whether effects are maintained when each of these types of indoor NE is examined separately. Additionally, we cannot exclude other types of NE, such as outdoor NE or more immersive experiences in nature at the workplace (such as regeneration pods⁶⁸), that may drive similar benefits among workers with less dispositional NR. As this study only examined the influence of NR, future work could examine whether other workers' values and traits, such as openness to experience, may explain the variability in outcomes reported in past studies⁶⁹. Additionally, we could not confirm the moderating role of NR in the relationship between NE and vigor; however, this does not exclude the possibility that NR moderates the relationship between NE and other mechanisms. Thus, the moderating role of NR should be tested with other mediators, such as stress or burnout reduction. Finally, owing to the study design, we cannot rule out a recursive relationship between NR and NE, i.e., more indoor NE nurtures NR among workers, as past studies have suggested^{40,70,71}. Future experimental studies could explore this question and examine whether increased NR is a possible mediating mechanism in workplace interventions.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on request.

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References

- Morrison, R. L. & Macky, K. A. The demands and resources arising from shared office spaces. *Appl. Ergon.* **60**, 103–115 (2017).
- Colenberg, S., Jylhä, T. & Arkesteijn, M. The relationship between interior office space and employee health and well-being – a literature review. *Build. Res. Inf.* **49**, 352–366 (2021).
- Richardson, M. et al. Nature: A new paradigm for well-being and ergonomics. *Ergonomics* **60**, 292–305 (2017).
- Lamb, S. & Kwok, K. C. A longitudinal investigation of work environment stressors on the performance and wellbeing of office workers. *Appl. Ergon.* **52**, 104–111 (2016).
- Lei, Q., Lau, S. S. Y., Yuan, C. & Qi, Y. Post-occupancy evaluation of the biophilic design in the workplace for health and wellbeing. *Buildings* **12**, 417 (2022).
- McMahan, E., Estes, D., Murfin, J. S. & Bryan, C. M. Nature connectedness moderates the effect of nature exposure on explicit and implicit measures of emotion. *J. Posit. Psychol. Wellbeing* **1**, 128–148 (2018).
- Morrison, R. L. & Smollan, R. K. Open plan office space? If you're going to do it, do it right: A fourteen-month longitudinal case study. *Appl. Ergon.* **82**(102933), 102933 (2020).
- Klotz, A. C. & Bolino, M. C. Bringing the great outdoors into the workplace: The energizing effect of biophilic work design. *Acad. Manag. Rev.* **46**, 231–251 (2021).
- Bringslimark, T., Hartig, T. & Patil, G. G. Psychological benefits of indoor plants in workplaces: Putting experimental results into context. *HortScience* **42**, 581–587 (2007).
- Dravigne, A., Waliczek, T. M., Lineberger, R. D. & Zajicek, J. M. The effect of live plants and window views of green spaces on employee perceptions of job satisfaction. *HortScience* **43**, 183–187 (2008).
- Kaplan, S. The restorative benefits of nature: Toward an integrative framework. *J. Environ. Psychol.* **5**, 69–82 (1995).
- Kaplan, R., Bardwell, L. V., Ford, H. A. & Kaplan, S. The corporate back-40: Employee benefits of wildlife enhancement efforts on corporate land. *Hum. Dimens. Wildl.* **1**, 1–13 (1996).
- Hyvönen, K. et al. Profiles of nature exposure and outdoor activities associated with occupational well-being among employees. *Front. Psychol.* **9**, 754 (2018).
- Largo-Wight, E., Chen, W. W., Dodd, V. & Weiler, R. Healthy workplaces: The effects of nature contact at work on employee stress and health. *Public Health Rep.* **126**, 124–130 (2011).
- Pati, D., Harvey, T. E. Jr. & Barach, P. Relationships between exterior views and nurse stress: An exploratory examination. *HERD Health Environ. Res. Des. J.* **1**, 27–38 (2008).
- Korpela, K. et al. Nature exposure predicts well-being trajectory groups among employees across two years. *J. Environ. Psychol.* **52**, 81–91 (2017).
- Trau, D., Keenan, K. A., Goforth, M. & Large, V. Nature contacts: employee wellness in healthcare. *HERD Health Environ. Res. Des. J.* **9**, 47–62 (2016).
- Bergefurt, L., Weijs-Perrée, M., Appel-Meulenbroek, R., Arentze, T. & de Kort, Y. Satisfaction with activity-support and physical home-workspace characteristics in relation to mental health during the COVID-19 pandemic. *J. Environ. Psychol.* **81**, 101826 (2022).
- Zhang, D., Mui, K. W. & Ten Wong, L. T. Questions concerning indoor environmental quality (IEQ) models: The development and applications. *Appl. Sci.* **13**(5), 3343 (2023).
- Altomonte, S. et al. Ten questions concerning well-being in the built environment. *Build. Environ.* **180**, 106949 (2020).

21. Gillis, K. & Gatersleben, B. A review of psychological literature on the health and wellbeing benefits of biophilic design. *Buildings* **5**(3), 948–963 (2015).
22. Sadick, A. M. & Kamardeen, I. Enhancing employees' performance and well-being with nature exposure embedded office workplace design. *J. Build. Eng.* **32**, 101789 (2020).
23. Bratman, G. N., Hamilton, J. P. & Daily, G. C. The impacts of nature experience on human cognitive function and mental health. *Ann. N. Y. Acad. Sci.* **1249**, 118–136 (2012).
24. Sonnentag, S. & Niessen, C. Staying vigorous until work is over: The role of trait vigor, day-specific work experiences and recovery. *J. Occup. Organ. Psychol.* **81**, 435–458 (2008).
25. Schaufeli, W. B., Bakker, A. B. & Salanova, M. The measurement of work engagement with a short questionnaire: A cross-national study. *Educ. Psychol. Meas.* **66**, 701–716 (2006).
26. Schaufeli, W. B. & Bakker, A. B. Job demands, job resources, and their relationship with burnout and engagement: A multi-sample study. *J. Occup. Organ. Psychol.* **25**(3), 293–315 (2004).
27. Ulrich, R. S. et al. Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* **11**, 201–230 (1991).
28. McMahan, E. A. & Estes, D. The effect of contact with natural environments on positive and negative affect: A meta-analysis. *J. Posit. Psychol.* **10**(6), 507–519 (2015).
29. Ryan, R. M., Bernstein, J. H. & Brown, K. W. Weekends, work, and well-being: Psychological need satisfactions and day of the week effects on mood, vitality, and physical symptoms. *J. Soc. Clin. Psychol.* **29**, 95–122 (2010).
30. Christensen, M., Dyrstad, J. M. & Innstrand, S. T. Academic work engagement, resources and productivity: Empirical evidence with policy implications. *Stud. High. Educ.* **45**(1), 86–99 (2020).
31. Hanaysha, J. Testing the effects of employee engagement, work environment, and organizational learning on organizational commitment. *Procedia Soc. Behav. Sci.* **229**, 289–297 (2016).
32. Van De Voorde, K., Veld, M. & Van Veldhoven, M. Connecting empowerment-focused HRM and labour productivity to work engagement: The mediating role of job demands and resources. *Hum. Resour. Manag. J.* **26**(2), 192–210 (2016).
33. Korpela, K., De Bloom, J., Sianoja, M., Pasanen, T. & Kinnunen, U. Nature at home and at work: Naturally good? Links between window views, indoor plants, outdoor activities and employee well-being over one year. *Landsc. Urban Plan.* **160**, 38–47 (2017).
34. Steidle, A., Gonzalez-Morales, M. G., Hoppe, A., Michel, A. & O'Shea, D. Energizing respites from work: A randomized controlled study on respite interventions. *Eur. J. Work Organ. Psychol.* **26**, 650–662 (2017).
35. Hartig, T., Mitchell, R., De Vries, S. & Frumkin, H. Nature and health. *Annu. Rev. Public Health* **35**, 207–228 (2014).
36. Capaldi, C. A., Passmore, H. A., Nisbet, E. K., Zelenski, J. M. & Dopko, R. L. Flourishing in nature: A review of the benefits of connecting with nature and its application as a wellbeing intervention. *Int. J. Wellbeing* **5**, 1–16 (2015).
37. Bowler, D. E., Buyung-Ali, L. M., Knight, T. M. & Pullin, A. S. A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health* **10**, 1–10 (2010).
38. Menardo, E., Brondino, M., Hall, R. & Pasini, M. Restorativeness in natural and urban environments: a meta-analysis. *Psychol. Rep.* **124**, 417–437 (2021).
39. Tang, I. C., Sullivan, W. C. & Chang, C. Y. Perceptual evaluation of natural landscapes: The role of the individual connection to nature. *Environ. Behav.* **47**, 595–617 (2015).
40. Berto, R., Barbiero, G., Barbiero, P. & Senes, G. An individual's connection to nature can affect perceived restorativeness of natural environments. Some observations about biophilia. *Behav. Sci.* **8**, 34 (2018).
41. Oyserman, D. Identity-based motivation and consumer behavior. *J. Consum. Psychol.* **19**, 276–279 (2009).
42. Reed, A. II., Forehand, M. R., Puntoni, S. & Warlop, L. Identity-based consumer behavior. *Int. J. Res. Mark.* **29**, 310–321 (2012).
43. Martin, L. et al. Nature contact, nature connectedness and associations with health, wellbeing and pro-environmental behaviours. *J. Environ. Psychol.* **68**, 101389 (2020).
44. Mackay, C. M. & Schmitt, M. T. Do people who feel connected to nature do more to protect it? A meta-analysis. *J. Environ. Psychol.* **65**, 101323 (2019).
45. Pritchard, A., Richardson, M., Sheffield, D. & McEwan, K. The relationship between nature connectedness and eudaimonic well-being: A meta-analysis. *J. Happiness Stud.* **21**, 1145–1167 (2020).
46. Howell, A. J., Passmore, H. A. & Buro, K. Meaning in nature: Meaning in life as a mediator of the relationship between nature connectedness and well-being. *J. Happiness Stud.* **14**, 1681–1696 (2013).
47. Nisbet, E. K., Zelenski, J. M. & Murphy, S. A. Happiness is in our nature: Exploring nature relatedness as a contributor to subjective well-being. *J. Happiness Stud.* **12**, 303–322 (2011).
48. Zelenski, J. M. & Nisbet, E. K. Happiness and feeling connected: The distinct role of nature relatedness. *Environ. Behav.* **46**, 3–23 (2014).
49. Capaldi, C. A., Dopko, R. L. & Zelenski, J. M. The relationship between nature connectedness and happiness: A meta-analysis. *Front. Psychol.* **976**, 92737 (2014).
50. Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y. & Podsakoff, N. P. Common method biases in behavioral research: a critical review of the literature and recommended remedies. *J. Appl. Psychol.* **88**, 879–903 (2003).
51. van Esch, E., Minjock, R., Colarelli, S. M. & Hirsch, S. Office window views: View features trump nature in predicting employee well-being. *J. Environ. Psychol.* **64**, 56–64 (2019).
52. Nisbet, E. K. & Zelenski, J. M. The NR-6: a new brief measure of nature relatedness. *Front. Psychol.* **4**, 813 (2013).
53. Merino, A., Valor, C. & Redondo, R. Connectedness is in my character: the relationship between nature relatedness and character strengths. *Environ. Educ. Res.* **26**, 1707–1728 (2020).
54. Extremera, N., Sánchez-García, M., Durán, M. A. & Rey, L. Examining the psychometric properties of the Utrecht work engagement scale in two Spanish multi-occupational samples. *Int. J. Sel. Assess.* **20**, 105–110 (2012).
55. Luna-Arocas, R. & Danvila-del-Valle, I. Does positive wellbeing predict job performance three months later?. *Appl. Res. Qual. Life* **16**, 1555–1569 (2021).
56. Clements-Croome, D. & Kaluarachchi, Y. Assessment and measurement of productivity. In *Creating the Productive Workplace* (ed. Croome, Derek) 151–188 (CRC Press, 1999).
57. Diener, E. D., Emmons, R. A., Larsen, R. J. & Griffin, S. The satisfaction with life scale. *J. Pers. Assess.* **49**, 71–75 (1985).
58. Martínez, M. J. C. et al. Fiabilidad y validez de la Escala de Satisfacción con la Vida de Diener en una muestra de mujeres embarazadas y puerperas. *Psicothema* **16**, 448–455 (2004).
59. Hills, P. & Argyle, M. The Oxford happiness questionnaire: a compact scale for the measurement of psychological well-being. *Pers. Individ. Dif.* **33**, 1073–1082 (2002).
60. Tomás-Sábado, J., Edo-Gual, M., Aradilla-Herrero, A., & Sorribes, J. V. Preliminary psychometric properties of the Spanish form of the Oxford Happiness Questionnaire Short-Form (OHQ-SF). *Comunicación presentada en el 15º Congreso Virtual de Psiquiatría* (2014, February).
61. Green, C., Jegadeesh, N. & Tang, Y. Gender and job performance: Evidence from Wall Street. *Financ. Anal. J.* **65**, 65–78 (2009).
62. Alessandri, G., Truxillo, D. M., Tisak, J., Fagnani, C. & Borgogni, L. Within-individual age-related trends, cycles, and event-driven changes in job performance: A career-span perspective. *J. Bus. Psychol.* **35**, 643–662 (2020).
63. Kamalanabhan, T. J., Sai, L. P. & Mayuri, D. Employee engagement and job satisfaction in the information technology industry. *Psychol. Rep.* **105**, 759–770 (2009).
64. Aiken, L. S., West, S. G. & Reno, R. R. *Multiple Regression: Testing and Interpreting Interactions* (Sage, 1991).

65. Giusti, M. & Samuelsson, K. The regenerative compatibility: A synergy between healthy ecosystems, environmental attitudes, and restorative experiences. *PLoS ONE* **15**, e0227311 (2020).
66. Morton, T. A., van der Bles, A. M. & Haslam, S. A. Seeing our self reflected in the world around us: The role of identity in making (natural) environments restorative. *J. Environ. Psychol.* **49**, 65–77 (2017).
67. Korpela, K., Savonen, E. M., Anttila, S., Pasanen, T. & Ratcliffe, E. Enhancing wellbeing with psychological tasks along forest trails. *Urban For. Urban Green.* **26**, 25–30 (2017).
68. Roskams, M. & Haynes, B. A randomised field experiment to test the restorative properties of purpose-built biophilic “regeneration pods”. *J. Corp. Real Estate* **22**, 297–312 (2020).
69. Gritzka, S., MacIntyre, T. E., Dörfel, D., Baker-Blanc, J. L. & Calogiuri, G. The effects of workplace nature-based interventions on the mental health and well-being of employees: a systematic review. *Front. Psychiatry* <https://doi.org/10.3389/fpsyt.2020.00323> (2020).
70. Mayer, F. S., Frantz, C. M., Bruehlman-Senecal, E. & Dolliver, K. Why is nature beneficial? The role of connectedness to nature. *Environ. Behav.* **41**, 607–643 (2009).
71. Nisbet, E. K., Zelenski, J. M. & Murphy, S. A. The nature relatedness scale: Linking individuals’ connection with nature to environmental concern and behavior. *Environ. Behav.* **41**, 715–740 (2009).

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Declarations

Competing interests

The authors declare no competing interests.

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