A randomised field experiment to test the restorative properties of purpose-built biophilic 'regeneration pods'

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Abstract

Purpose: There has been limited investigation into how 'biophilic design' (i.e., the integration of nature within the built environment) can be effectively used within the workplace to facilitate the process of psychological restoration. This study focused in particular on the effectiveness of biophilic "restoration pods" in promoting recovery from stress.

Design/Methodology/Approach: A randomised field experiment was conducted. Thirty-two employees from a participating organisation completed two tests replicating typical office work (proofreading and arithmetic) and subjective ratings of stress, anxiety, and task-load both before and after a 10-minute micro-break, taken in either the regeneration pods (treatment group) or an ordinary meeting room (control group).

Findings: The results showed that participants who took their break in the regeneration pod reported lower post-break anxiety and perceived task-load, and higher post-break arithmetic task performance, than the control group.

Practical implications: The findings suggest that purpose-built spaces for restoration within office buildings will be effective for helping employees to proactively manage their stress levels whilst at work. Biophilic design principles will enhance the effectiveness of these spaces, and this does not necessarily need to involve direct exposure to plants or views of nature.

Originality/Value: To our knowledge, this is the first randomised field experiment to test the effectiveness of a purpose-built space for restoration within offices. Additionally, the study explores biophilic design strategies which had previously received limited attention in the research literature.

One of the major health concerns for modern knowledge workers is work-related stress, which is experienced whenever the perceived demands of a situation exceed the perceived ability to cope. High work performance necessitates the prolonged use of different higher-order cognitive functions coupled with self-regulatory processes (e.g., focused attention, inhibitory control). However, the psychological resource responsible for self-regulation (termed the "ego") is limited and can become quickly depleted (Baumeister and Vohs, 2007), particularly in open-plan offices where numerous non-task-related environmental demands (e.g., poor indoor air quality, auditory and visual distractions) further impede effective task completion (authors, manuscript submitted for review).

To mitigate the pernicious effects of stress, organisations should consider opportunities to facilitate *restoration* (i.e., the process of renewal in which depleted social, psychological, or physical resources are replenished; Hartig, 2004) in the workplace. Importantly, the restoration of attentional resources is expedited when the individual detaches psychologically from work, practices physiological relaxation, and experiences high autonomy (Sonnentag and Fritz, 2007). For this reason, work breaks – even "micro-breaks" lasting ten minutes or less – are considered to be an effective means of helping employees to proactively restore depleted attentional resources and effectively cope with psychophysiological stress throughout the working day (Sonnentag *et al.,* 2012; Wendsche *et al.,* 2016).

To date, limited attention has been paid to the ways in which spaces for restoration within offices can be most effectively designed. As such, the present study aimed to test the effectiveness of using 'biophilic' design strategies for this purpose.

What is biophilic design?

The “biophilia hypothesis” suggests that humans possess an innate tendency to seek connections with nature and other forms of life, and that nature contact plays a crucial role in supporting human health and well-being (Wilson, 1984). Indeed, it has been repeatedly demonstrated that contact with nature leads to reductions in psychological, physiological and neurological indicators of stress (e.g., Hartig *et al.*, 2014; Norwood *et al.,* 2019; Park *et al.,* 2010). Popular theories to account for the beneficial effects of nature exposure are grounded in evolutionary psychology. For example, Attention Restoration Theory (ART; Kaplan, 1995) argues that humans are evolutionarily primed to find natural environments ‘softly fascinating’, meaning that they can be viewed with effortless attention, allowing the depleted capacity for directed attention to recover. Similarly, Stress Reduction Theory (SRT; Ulrich *et al.,* 1991) proposes that exposure to nature elicits positive emotions and feelings of interest and tranquillity, prompting a return to equilibrium from the physiological activation instigated by a stressor.

Just as contact with nature is associated with improved psychological functioning, so too is insufficient nature contact associated with psychological deficits (e.g., Louv, 2011). This is a particular concern in the modern developed world, where increasing urbanisation has left many inhabitants unable to experience the benefits associated with nature contact. Hence, there is an emerging trend within architecture and urban design for ‘biophilic design, comprising strategies aimed at “maintaining, enhancing, and restoring the beneficial experience of nature in the built environment” (Kellert and Heerwagen, 2013).

In an effort to arrange different biophilic design strategies into a coherent framework, Ryan *et al.* (2014) proposed that 14 ‘patterns’ of biophilic design strategies could be grouped into three broad categories: (1) “nature in the space” (the direct integration of nature within the built environment, e.g., through window views of nature or interior planting); (2) “natural analogues” (the indirect evocation of nature, e.g., through wooden furnishings or the use of complex biomorphic designs); and (3) "nature of the space" (mimicry of the spatial configurations found in nature, e.g., designing spaces which provide both prospect and refuge).

Biophilic design within office spaces

In recent decades, workplace researchers and practitioners have increasingly considered the potential benefits of biophilic design within office spaces, focusing largely on 'nature in the space' design strategies. Consistently, such studies point to the conclusion that biophilic design positively supports the well-being and productivity of office occupants. For example, comparisons of office spaces with and without plants have demonstrated that the presence of plants is variously associated with improvements in physiological stress and objective task performance (Lohr *et al.,* 1995), attention capacity (Raanaas *et al.,* 2011), and self-reported concentration and productivity (Nieuwenhuis *et al.,* 2014). Similarly, views of nature, compared with views of urban/built environments, are associated with improvements in stress, positive affect, sustained attention, task performance, and general perceptions of health (Jiang *et al.,* 2019; Lee *et al.,* 2015, 2018; Kaplan, 1993; Ulrich *et al.,* 1991;).

These benefits are typically accounted for with reference to ART and SRT. By directing attention away from work tasks and toward natural features within the field of vision, employees are able to prompt "micro-restorative experiences" which enable them to continually restore attentional resources deplete through the task-related and non-task-related demands of everyday working life. In doing so, they are able to more effectively moderate stress and attention on an ongoing basis, resulting in improved well-being and productivity at work.

Whilst these studies have provided useful insight into how biophilic design can be effectively implemented within the workplace, one limitation that has been noted is that the vast majority of the biophilic design literature focuses solely on the aforementioned 'nature in the space' strategies, and less is known about the effects of other aspects of biophilic design (Yin *et al*., 2019). That is, it remains unclear whether similar benefits could be elicited in office spaces through the use of 'natural analogues' and 'nature of the space' strategies.

The Present Study

The opportunity to address this gap was presented to the present researchers by a participating organisation who had recently commissioned the construction of two "regeneration pods" (shown in Figure 1) for their office, to be used as a purpose-built space for recuperation. These were designed by an architect, entirely independent of the research team, who explicitly used several biophilic design strategies which have been little considered in previous research.

First, the pods were constructed using bamboo wood and designed to follow the structural logic of nature using complex biomorphic forms, reflecting both the 'material connection with nature' and 'biomorphic forms and patterns' strategies from the 'natural analogues' biophilic design category (Ryan *et al.,* 2014). There is some suggestion in the research literature to suggest that these should be associated with improved outcomes. For example, one literature review concluded that there is good early evidence to suggest that exposure to wooden environments also reduces numerous psychophysiological indicators of stress (Burnard and Katnar, 2015), although the need for more robust research was noted.

Second, the pods were designed in accordance with prospect-refuge theory, meeting a prescription from the 'nature of the space' category (Ryan *et al.,* 2014). In line with the evolutionary assumption that humans have an innate desire to observe without being seen, the pods (located in an enclosed room in the corner of the floor plate) provide significant visual and auditory enclosure from other parts of the office, but grant the user a clear view from the window. Due to the location of the office (in central London, England), there was very limited greenery present in the window view, however it was assumed that the expansive view and daylight exposure would be valuable nonetheless. The room housing the pods was decorated with several cacti plants, although these are not directly in the user's line of sight during use.

Finally, the pods also allow users to initiate a 10-minute soundscape featuring calming sounds of nature, played through overhead speakers. This meets the criteria for 'non-visual connection with nature' in the 'nature in the space' category (Ryan *et al.,* 2014), and corresponds with previous research indicating that hearing natural soundscapes is associated with improvements in mood (Benfield *et al.,* 2014). Overall, the combination of these hitherto under-considered biophilic design strategies was predicted to yield similar benefits to those previously demonstrated through the use of interior plants and window views to nature.

FIGURE 1 HERE

The aim of the present study was to test this prediction. Specifically, a randomised field experiment was conducted to explore whether a micro-break taken within a "regeneration pod" had greater benefits than a micro-break within an ordinary enclosed meeting room. It was hypothesised that participants in the regeneration pod group would experience even lower post-break levels of subjective anxiety *(H_1)* and stress (H_2), higher post-break performance on proofreading (H_3) and arithmetic (H_4) tasks, and lower perceived task-load during task completion (H_5), relative to those in the control group.

Methods

Study Design and Context

Data were collected at the head office of the large private-sector organisation who had commissioned the regeneration pods. A randomised field experiment design was adopted, following on from similar studies by Lee *et al.* (2018) and Jiang *et al.* (2019). Employees were randomly assigned (using a random number generator) to one of two conditions: (a) a 'control' condition involving a 10-minute break in an enclosed meeting room; or (b) a 'treatment' condition involving a 10-minute break in the regeneration pod. Full ethics approval for the experimental procedure was granted by the ethics committee at the authors' university.

The enclosed meeting room was located on the interior of the floor plate, and included a central table surrounded by six desk chairs, and a television monitor fastened to the wall opposite the door. The room did not feature any interior plants or artwork, nor were any natural materials were used in the room's furniture. The only window in the room was frosted to provide privacy from the adjacent open-plan office space. The room accommodating the regeneration pods (which was described in more detail in the

Introduction) was located approximately 10 metres away from the entrance of the meeting room, and featured ceiling-to-floor windows providing views to outdoors.

To get from one room to the other, participants needed to return briefly to the main office space. This was a large open-plan area designed to accommodate approximately 300 employees (through a combination of desk space, secondary seating areas, and informal meeting spaces), where small partitions (e.g., lockers, furniture) rather than interior walls were used to partition different working 'neighbourhoods'. A modest degree of biophilic design was implemented within this main space, limited to interior plants placed infrequently between neighbourhoods.

Participants

An e-mail list was used to contact approximately 200 employees who used the office as their primary working location with information about the study and an invitation to participate. Additionally, the lead researcher verbally communicated information about the study to others whilst working from the office. No tangible incentives were offered in return for participation. Rather than setting an *a priori* specification for minimum sample size, the aim was to recruit the maximum number of participants from the pool of regular employees.

In total, approximately 50 participants volunteered to participate in the study, however not all of these attended their allotted experimental session. As such, the overall sample size comprised 32 employees. The sample consisted of 19 males and 13 females, and the mean age was 32.9 (range 24 to 46). Seventeen participants were native speakers of English, whereas 15 participants spoke English as a second language. Efforts were made to balance these characteristics across the two experimental conditions, however non-attendance to experimental sessions led to slight imbalances. As such, during the data analysis it was tested whether demographic characteristics should be included as covariates prior to running the main analyses.

Procedure

Depending on their availability, participants were asked to come to the enclosed meeting room for a 40-minute session on either a Thursday or Friday afternoon, with a starting time between 2:00pm and 4:00pm. Participants either completed the procedure alone or with one other participant, again because of differing levels of availability.

Upon arrival to the meeting room, participants were asked to relax for five minutes in order to reduce the impact of prior experiences upon baseline measures. They were then asked to read a participant information sheet, and sign a consent form if they agreed to the terms of the study. At this point, they were given a paper questionnaire booklet and asked to fill in demographic information and the first round of subjective measures (*T1*).

Next, they were asked to complete three tasks, with a two-minute time limit for each. These tasks included a proofreading task and an arithmetic task, which were intentionally designed to be demanding in an attempt to replicate the type of stress an employee might experience during a difficult day at work. As a further ego-depletion manipulation, the first round of tasks also included a tracing task which, unbeknownst to the participants, was impossible to complete (adapted slightly from Lurquin, 2013; see supplementary materials). After the tasks were completed, participants were asked to turn to the next page in the questionnaire booklet to complete the second round of subjective measures (*T2).*

At this point, participants were instructed to take a 10-minute break and asked to "relax or unwind in your normal way", with the exception that they should not use their mobile phones or laptops during the break. Those in the treatment group were asked to walk the short distance to the regeneration pod for their break. Before starting their break, they were instructed to use their access card to initiate the acoustic soundscape through the overhead speakers. Those in the control group were asked to remain in the meeting room. In all cases, the lead researcher left the room with the questionnaire booklets, and then notified the participant(s) when the 10 minutes had elapsed, so that the session could resume in the meeting room. Immediately after the break, participants completed the third round of subjective measures *(T3)*. Finally, participants completed new versions of the arithmetic and proofreading task, followed by the fourth round of subjective measures *(T4)*.

Once the booklet was completed, participation in the study was over, so participants were thanked for their time and debriefed about the nature of the unsolvable tracing task. Participants who were not assigned to the experimental condition were encouraged to use the restoration pods in future, so that they did not experience any disadvantage as a result of how the treatment was assigned.

Measures

Demographic information

Participants indicated their gender and year of birth. Additionally, they were asked to indicate whether English was their first language, as it was reasoned that this might affect performance on the proofreading task.

Subjective measures

To increase the sensitivity of participant's questionnaire responses, visual analogue scales were used within the questionnaire rather than numeric rating scales. Specifically, participants were instructed to use an 'X' to mark the intensity with which they currently felt different emotions or sensations. In each case, the line for the scale was exactly 10 centimetres long, so a quantitative score for each measure was derived by using a ruler to calculate the exact point at which the X was drawn.

Specifically, on all four measurement occasions participants rated the extent to which they were currently experiencing four emotions (anxiety, calm, relaxed, tense), taken from the anxiety-comfort subscale of the Multi-Affect Indicator (Warr, 2013). The scale ranged from "Not at all" to "Completely". Responses to 'calm' and 'relaxed' were reverse-scored, and subsequently the average of the four items was taken as the score for subjective *anxiety.* The four items showed high internal consistency ($\alpha = 0.84$). At the same time points, one additional item was included for participants to rate their subjective *stress* levels, using exactly the same scale.

At T2 and T4 only, four items were taken from the NASA Task-Load index (NASA-TLX; NASA, 2019) to measure *perceived mental demand, temporal demand, perceived effort,* and *frustration* experienced during the tasks that had just been completed. The scale for these items ranged from "Very low" to "Very high". The responses to these items were summated to attain a single score for *perceived task-load* between 0 and 40, and also showed good internal consistency ($\alpha = 0.79$).

Task performance

A proofreading task and an arithmetic task were used to measure cognitive performance, as these approximately replicate real office activities, and have also been used previously to induce cognitive load (Jiang *et al.,* 2019).

The proofreading task was adapted slightly from previous studies (e.g., Brunye *et al*., 2012), and can be considered a measure of verbal-semantic processing ability. Participants read a short passage of text, which they were told contained "numerous spelling errors, verb tense errors, and other typological errors", and were instructed to circle or underline any errors that they could identify. Each passage contained 16 errors in total: four simple local errors (misspellings of 1-2 syllable words), four complex local errors (misspellings of 3-4 syllable words), four simple global errors (homophones), and four complex global errors (subject-verb disagreement or verb tense mis-use). Both passages were adapted from Wikipedia entries, and were approximately matched on both word length and the Gunning Fog Index of text readability (264 words and a Gunning Fog score of 17.5 for a passage on 'air conditioning', and 262 words and a Gunning Fog score of 18 for a passage on 'solar energy'). Proofreading performance was scored as the number of errors correctly identified.

The second test was an adapted version of the Serial Sevens test (Hayman, 1942), designed as a measure of mental arithmetic. Whereas the original test requires participants to verbally perform serial subtractions in sevens from a starting number, in the present study the calculations were performed on paper using different numbers for serial subtractions. Participants were given ten questions to complete within two minutes, each involving five serial subtractions from a starting number. The starting number was a randomly-generated three-digit (first 5 questions) or four-digit number (last 5 questions). The number to be serially subtracted was randomly chosen from 3 to 9 for the first seven questions, and from 10 to 20 for the last three questions (although multiples of 5 and 10 were not used). These measures ensured that the questions became increasingly difficult as the task progressed, and was matched in difficulty between the pre- and post-break tests. In total, there were five possible correct answers for each question, meaning that the maximum score was 50.

Results

All statistical analyses were performed using R Studio. The code that was used for the analysis, including the different packages that were used, is available as a supplementary file upon request from the primary author.

A series of analysis of variance (ANOVA) models were used to test the hypotheses. Two outcomes (perceived stress and anxiety) were measured at all four time points, so to analyse these outcomes 2 (Condition: Treatment vs Control) x 4 (Time: T1, T2, T3, and T4) mixed ANOVAs were performed (summary statistics shown in Table 1), computed using Type III sum of squares because a significant interaction was expected. Generalised eta-squared ($\eta 2_G$) is reported as the measure of the effect size for predictors in these models, and is interpreted using Draper's (2020) recommendations.

The other three outcomes (proofreading performance, arithmetic performance, perceived task-load) were measured at T2 and T4 only, and so baseline-adjusted analyses of co-variance (ANVOCAs) were used to test the hypotheses (summary statistics shown in Table 2). No interaction terms were included in these models, so test statistics were calculated using Type II sum of squares. Partial eta-squared ($\eta 2_p$) is reported as the measure of the effect size for predictors in these models, and is also interpreted using Draper's (2020) guidelines.

Testing potential confounds

Prior to the main analyses, the influence of three potential confounds (Gender, Age, and whether or not English was the participant's first language) were assessed for each of the outcomes using *t*-tests and Pearson's correlation. The results confirmed that male participants in our sample scored significantly higher on the arithmetic task than female participants ($M = 20$ vs $M = 14.54$; $p = 0.009$), and that male participants also perceived lower task-load than female participants ($M = 27.32$ vs $M = 30.43$; $p = 0.05$). As such, gender was included as a covariate in the models for arithmetic task performance and perceived task-load. Surprisingly, there was no significant effect of native language upon proofreading performance ($p = 0.54$). Neither were any of the other associations between potential confounds and outcome variables statistically significant (p-values > 0.05). Thus, the other models were fitted without the potential confounds to avoid over-parameterisation.

Mixed ANOVAs

In the model for anxiety, Shapiro-Wilks test and Levene's test were both non-significant, indicating that the assumptions of normality and homogeneity of variance had been met. However, Mauchly's test was significant ($p = 0.046$), indicating that the assumption of sphericity had been violated. As such, the degrees of freedom and p-values for the within-subject measures were corrected using the Greenhouse-Geisser method.

The results indicated significant moderate effects of both condition ($\eta^2_G = 0.2$, $p < 0.0001$) and time ($\eta^2_G = 0.23$, $p < 0.0001$). The interaction term was also significant with a small effect size ($\eta^2_G = 0.06$, $p = 0.019$), indicating that the effect of condition differed at different points in time. *Post-hoc* contrasts were tested using Tukey's procedure. The contrasts for time indicated a significant increase in anxiety from T1 ($M = 4.4$) to T2 ($M = 5.54$) ($p = 0.0007$), confirming that the manipulation (i.e., the completion of difficult tasks) had the intended effect. There was also a significant reduction in anxiety for both groups at T3 ($M = 3.45$) ($p < 0.0001$), confirming the general assumption that the 10-minute break would effectively reduce anxiety.

The interaction plot is shown in Figure 2, which reports the estimated means (including a 95% confidence interval) for both groups at each time point alongside the *p*-value of the difference test. As shown, there were no significant between-group differences at T1 or T2. At T3, perceived anxiety was significantly lower in the treatment group ($M = 2.56$) than the control group ($M = 4.34$) ($p = 0.01$). Similarly, anxiety was also significantly lower in the treatment group ($M = 3.56$) than the control group ($M = 5.83$) ($p = 0.0005$) at T4. As such, it was concluded that the regeneration pods were more effective at reducing anxiety than the meeting room, in support of H_1.

FIGURE 2 HERE

In the model for stress, Shapiro-Wilks test detected a violation of normality ($p = 0.003$). However, visual inspection of the Q-Q plot revealed an approximate normal distribution and sample size was equal across groups, so it was determined that the ANOVA would be robust to a small departure from normality. Levene's test and Mauchly's test were both non-significant, indicating that assumptions of homogeneity of variance and sphericity had been met.

The results indicated a non-significant main effect of condition ($\eta^2_G = 0.03$, $p = 0.24$). However, both the main effect of time ($\eta^2_G = 0.11$, $p < 0.0001$) and the condition by time interaction ($\eta^2_G = 0.06$, $p = 0.0002$) were statistically significant. Again, Tukey's test was computed to investigate the nature of the significant differences. For the main effect of time, perceived stress for all participants increased from T1 ($M = 5.23$) to T2 ($M = 6.17$) ($p = 0.016$), again confirming that the manipulation was successful. There was also a significant decrease in stress at T3 ($M = 4.06$) ($p < 0.0001$), again confirming the general assumption that a 10-minute break would effectively reduce stress.

The contrasts for the interaction, shown in Figure 3, were not significant at any of the four time points, although the between-group differences were larger and in the expected direction at both T3 ($M = 5.09$ for control vs $M = 3.02$ for treatment, $p = 0.15$) and T4 ($M = 5.99$ for control vs $M = 4.44$, $p = 0.48$). However, because these differences were not statistically significant, it could not be concluded that the regeneration pods were more effective at alleviating stress than the meeting room. Therefore, H_2 was not supported.

FIGURE 3 HERE

TABLE 1 HERE

Baseline-Adjusted ANCOVAs

The baseline-adjusted ANCOVA models for *proofreading performance, arithmetic performance,* and *perceived task-load* all met the assumptions of normality, homogeneity of variance, and homogeneity of regression slopes.

The model for proofreading performance indicated that although the effect sizes were moderate, neither the effect of condition ($\eta^2_p = 0.06$, $p = 0.17$) nor baseline proofreading performance ($\eta^2_p = 0.08$, $p = 0.13$) was statistically significant. Although the estimated means indicated slightly higher post-break proofreading performance in the treatment group

(M = 8.41) than the control group (M = 6.97), it could not be concluded that this difference was not due to chance. Therefore, H_3 was not supported.

In the model for arithmetic performance, there were strong effects of both condition ($\eta^2_p = 0.24$, $p = 0.005$) and baseline arithmetic performance ($\eta^2_p = 0.51$, $p < 0.0001$), but the effect of gender was not statistically significant ($\eta^2_p = 0.03$, $p = 0.34$). The analysis was repeated without the covariate, leading to slight increases in the effect sizes for condition ($\eta^2_p = 0.26$, $p = 0.003$) and baseline arithmetic performance ($\eta^2_p = 0.57$, $p < 0.0001$). The adjusted means for condition from the original model showed that the treatment group (M = 19.85) significantly outperformed the control group (M = 15.71) on the post-break arithmetic task. Therefore, H_4 was supported.

Finally, the model for perceived task-load also showed strong effects of both condition ($\eta^2_p = 0.21$, $p = 0.01$) and baseline perceived task-load ($\eta^2_p = 0.46$, $p < 0.0001$), and a non-significant effect of gender ($\eta^2_p = 0.004$, $p = 0.74$). Again, the analysis was repeated without the covariate and the effect sizes of condition ($\eta^2_p = 0.23$, $p = 0.007$) and baseline perceived task-load ($\eta^2_p = 0.46$, $p < 0.0001$) increased by a small amount. The adjusted means for condition from the original model showed that the treatment group (M = 26.67) reported significantly lower perceived task-load on the second round of tests than the control group (M = 30.36), providing support for H_5.

TABLE 2 HERE

Discussion

The purpose of this study was to investigate whether a 10-minute micro-break in a "regeneration pod" had greater benefits than a micro-break in an enclosed meeting room. Overall, the results provided support for three out of five hypotheses, and where between-group contrasts were non-significant the differences were in the expected direction.

In line with assumptions, the micro-break had stress- and anxiety-reducing effects for all participants, supporting previous suggestions that they are an effective way of managing stress throughout the working day (e.g., Sonnentag *et al.,* 2012; Wendsche *et al.,* 2016). However, these benefits were enhanced for those participants who took their break in the regeneration pods rather than the meeting rooms. These participants reported comparatively lower levels of anxiety, both immediately post-break and during a second round of challenging tasks. They also performed better on an arithmetic task, and reported that the tasks were less demanding. Overall, the results are in line with the wider literature on biophilic design, as well as recent studies which also demonstrated that 'green' micro-breaks have unique benefits compared with micro-breaks in non-biophilic spaces (Jiang *et al.,* 2019; Lee *et al.,* 2015, 2018).

The findings can be interpreted with reference to ART (Kaplan, 1995). The completion of the challenging tasks (including the impossible tracing task) was attentionally-demanding, and led to increases in stress and anxiety. Attentional restoration appeared to occur more quickly amongst those who took their break in the regeneration pod rather than the meeting room, as evidenced by comparatively higher post-break arithmetic performance and lower perceived task-load. Although the effect of stress was not statistically significant, the trend of lower perceived stress in the regeneration pods group suggests that these participants may also have experienced comparatively greater improvements in stress, in line with SRT (Ulrich *et al.,* 1991).

Uniquely, our results demonstrate that office spaces do not necessarily need to incorporate 'nature in the space' biophilic design strategies (e.g., interior plants or direct views of nature) in order to be restorative. The regeneration pods looked out over a completely urban environment, with no plants in the user's direct line of vision. However, the construction used natural wooden materials, intentionally mimicked the refuge and complexity of nature, and allowed users to initiate an acoustic natural soundscape evoking the calming sounds of nature. Together, these features combined to form a restorative environment engendering similar benefits to those reported in spaces involving direct nature exposure. The finding that indirect nature evocation is also beneficial provides more flexibility for workplace designers seeking to use biophilic design strategies within offices. For example, in spaces where lush interior planting is deemed inappropriate, at least some of the benefits of biophilic design may still be derived through the use of wooden furnishings which mimic the spatial complexity of nature and/or acoustic soundscapes which enhance the immersive biophilic experience.

The results are especially relevant for the emerging practice of "activity-based" working, in which specific workspaces are designed for specific types of activity. Different workspaces within such offices are typically purely functional (e.g., spaces for collaborative work, spaces for focused individual work), however our results highlight that designing purpose-built spaces for restoration would also be a worthwhile investment. The effectiveness of the design can be enhanced through the biophilic strategies, providing opportunities for users to immerse themselves in 'softly fascinating' environments whilst detaching themselves from work. In this way, organisations can empower their employees to proactively manage their stress throughout the working day.

The opportunity to conduct research on previously under-considered biophilic design strategies in a real office environment was certainly welcome, and ensured that the findings have high external validity, due to the fact that real members of the target population (i.e., working adults) were studied directly in the context of interest (a real office environment). However, the opportunistic field design also introduced largely unavoidable limitations which may have affected the internal validity of the findings.

Most notably, it was not possible to perfectly match possible confounds in the treatment and control conditions. Ideally, the exact same room would have been used for the treatment and the control conditions, with the only difference being the presence or absence of the regeneration pods, so that the physical features of the room (e.g., access to daylight, room height and size, room colours) were controlled across conditions. However, due to the size of the pods and the complexity and cost associated with moving them, this was not possible. This also meant that treatment group participants had to walk a short distance before taking their break whereas control group participants remained still, which could also be a possible confound which affects the results. Therefore, it is not possible to fully conclude that the observed benefits were necessarily a result of the regeneration pods themselves.

On a similar note, even if the benefits could be attributed to the regeneration pods, the design of the study meant it was not possible to understand exactly which particular aspects of biophilic design (i.e., the wooden furnishings, the nature-mimicking design, the acoustic soundscape, or some combination of the three) contributed most strongly to psychological restoration. Again, this was unavoidable due to practical constraints in separately partitioning and testing different combinations of these factors. However, in future it will be valuable to complement field studies with laboratory studies in which it easier to individually add or remove the environmental factors of interest. The recent study by Yin *et al.* (2019) demonstrates how this might be achievable through the use of virtual reality techniques.

Possibly, research conducted using virtual reality could provide the initial validation for design techniques which are subsequently implemented and further tested in real workplaces.

A third limitation of the present study is that the potential sample was restricted to the regular users of the office. Amongst these, only a relatively small number volunteered to participate in the study, and so our analyses may have been underpowered to detect all significant differences between the groups. Indeed, this seems to be the most likely explanation as to why the between-group differences for perceived stress and proofreading task performance did not meet criteria for statistical significance. As such, it would be useful to repeat similar studies with larger samples in future.

Finally, and more generally, future research would also benefit from complementing subjective measures of stress with objective physiological measures, such as salivary cortisol, electrodermal activity, and/or neurological activity. Indeed, in the present study there was an attempt to meet this need by asking participants to wear biometric sensors which continuously measured electrodermal activity, but unfortunately these data could not be used in the analysis due to missingness when the data were retrieved. By combining objective and subjective measures of the dependent variables, researchers will benefit from a more comprehensive understanding of exactly how individuals respond to different types of environment.

Conclusions

Employees who took a 10-minute break in a purpose-built biophilic ‘regeneration pod’ reported post-break improvements in perceived anxiety, arithmetic performance, and perceived task-load, relative to those who took a 10-minute break in an ordinary meeting room. The regeneration pods featured neither the integration of plants nor direct views of nature, but rather created a biophilic environment through the use of natural materials in a design which mimicked the spatial complexity of nature, coupled with an acoustic natural soundscape. The findings highlight the flexibility in the types of methods designers might use when crafting biophilic spaces within offices, and demonstrate that these spaces could be highly valuable in enabling employees to proactively manage their stress levels throughout the working day.

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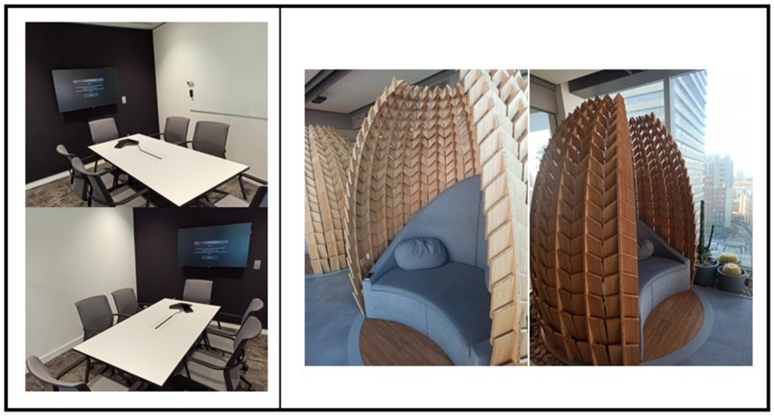


Figure 1: Images of the meeting room (control condition, left) and the regeneration pods (treatment condition, right)

338x190mm (96 x 96 DPI)

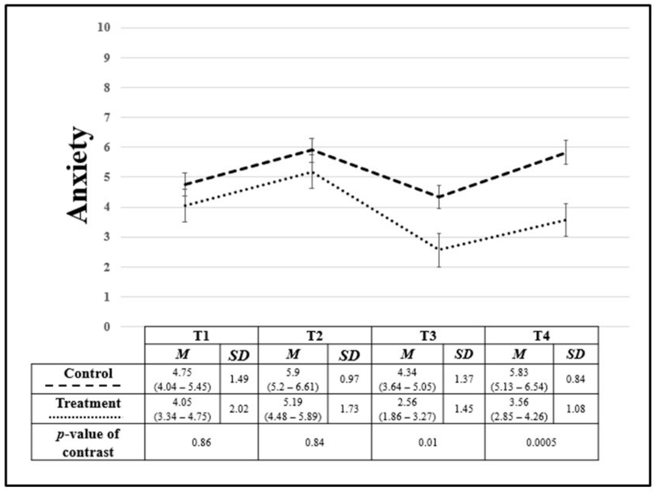
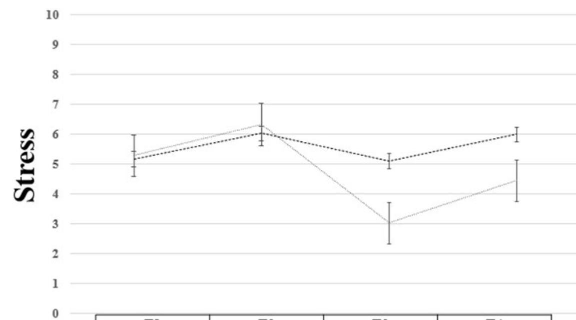


Figure 2: The condition by time interaction for perceived anxiety, including the mean (plus 95% confidence interval)
and standard deviation within each cell of the experimental design, as well as the p-value of the contrasts at each time point

338x190mm (96 x 96 DPI)



	T1		T2		T3		T4	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control - - - - - -	5.17 (4.08 – 6.27)	1.71	6.02 (4.93 - 7.11)	1.65	5.09 (4 – 6.18)	1.99	5.99 (4.9 – 7.09)	1.62
Treatment …………………	5.28 (4.19 – 6.37)	2.84	6.33 (5.24 – 7.42)	2.45	3.02 (1.93 – 4.12)	2.51	4.44 (3.35 – 5.53)	2.29
***p*-value of contrast**	1		1		0.15		0.48	

Figure 3: The condition by time interaction for perceived stress, including the mean (plus 95% confidence interval)
and standard deviation within each cell of the experimental design, as well as the p-value of the contrasts at each time point

338x190mm (96 x 96 DPI)

Table 1. A summary of the mixed ANOVA models for subjective anxiety and stress

	Univariate model for subjective anxiety (*N* = 32)		
	F	***η2_G***	***p***
Condition	14.54	0.2	<0.0001
Time	18.11	0.23	<0.0001
Condition x Time	3.79	0.06	0.019
	Univariate model for subjective stress (*N* = 32)		
Condition	1.43	0.03	0.24
Time	15.61	0.11	<0.0001
Condition x Time	7.31	0.06	0.0002

Effect size descriptors: *Small* ($0.02 < \eta^2_G < 0.13$), *Medium* ($0.13 < \eta^2_G < 0.26$), *Large* ($0.26 < \eta^2_G$)

Table 2. A summary of the baseline-adjusted ANCOVA models for proofreading performance, arithmetic performance, and perceived task-load

	Model Summary Statistics			**Adjusted Means (95% CI)**	
	F	***$\eta 2_p$***	***p***	**Control**	**Treatment**
Effect of Condition *(Proofreading task)*	2.00	0.06	0.17	6.97 (5.5 – 8.43)	8.41 (6.95 – 9.87)
Effect of Condition *(Arithmetic task)*	9.07	0.24	0.005	15.71 (13.74 – 17.68)	19.85 (17.88 – 21.82)
Effect of Condition *(Perceived task-load)*	6.99	0.21	0.01	30.36 (28.46 – 32.27)	26.67 (24.69 – 28.64)

Effect size descriptors: *Small* ($0.01 < \eta^2_p < 0.06$), *Medium* ($0.06 < \eta^2_p < 0.14$), *Large* ($0.14 < \eta^2_p$)