Landscape and Urban Planning

Does a natural environment enhance the effectiveness of Mindfulness-Based Stress Reduction (MBSR)? Examining the mental health and wellbeing, and nature connectedness benefits

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Abstract

This study investigated whether the impacts of a commonly used wellbeing intervention, Mindfulness-Based Stress Reduction (MBSR), are enhanced when combined with the benefits of exposure to a natural environment. Participants (n=99) were randomly assigned to a weekly one-hour MBSR in one of three different environments (i.e. natural outdoor, built outdoor and indoor environments) over a six-week period. Participants' wellbeing outcomes and nature connectedness were measured at baseline, during the intervention and at one-week and one-month follow up. The results show that the mental health and wellbeing outcomes of MBSR are greater when it carried out in a natural outdoor environment compared with indoor or built environments. Moreover, participants in the natural outdoor environment showed sustained improvements even after one month from completion of the intervention. This study supports the potential value of natural environments as settings for the enhancement of health care delivery and therapeutic interventions.

Highlights

- Participants in the MBSR programme in the natural outdoor environment reported reduced stress and rumination and enhanced reflection.

- MBSR participants in the natural outdoor environment reported greater nature connectedness than those in the built outdoor and indoor environments.
- The change in nature connectedness mediated the changes in participants' levels of reflection.

1. Introduction

Mental health disorders are one of the largest contributors to the burden of illness in the UK. Each year nearly 23% of UK adults seek medical advice about common mental health problems, such as depression, anxiety disorders and stress-related illness (McManus *et al*., 2016). With a record number of antidepressants being prescribed, and a greater demand for psychological therapies, health and social care providers are interested in cost-effective interventions both to prevent and to treat mental health disorders (Bragg and Atkins, 2016). Whilst a growing body of research has evidenced the salutogenic effects of the natural environment there has been limited application of these effects in policy and practice. England's 25 year environment plan signals an intention to "*scope out how we could connect people more systematically with green space to improve mental health, using the natural environment as a resource for preventative and therapeutic purposes*". However, despite some progress in the area of green care (e.g. Bragg and Atkins, 2016), few studies have examined the effect of combining a therapeutic intervention with restorative experiences, such as exposure to nature. The current study investigated whether the mental health and wellbeing benefits of MBSR are enhanced when it is carried out in a natural environment.

Natural environment and wellbeing

There is growing recognition of the important role of natural environments in supporting health and wellbeing (Wood *et al*., 2017), particularly as a key element in preventing and dealing with mental illness (Lachowycz and Jones, 2013). Van den Berg *et al*. (2010) found that natural environments in residential areas serve as a buffer against the negative health impact of stressful life events. The British Household Panel Survey also showed that individuals who moved to greener neighbourhoods had significantly improved mental health after the move, and conversely those who moved to less green neighbourhoods had significantly poorer mental health (Alcock *et al*., 2014). With the increasing interest in the wellbeing benefits of natural environments, environmental organisations are starting to provide a wide range of nature-based activities/programmes for vulnerable groups (e.g. the Wild at Heart programme run by Sheffield & Rotherham Wildlife Trust, 2019), including those suffering from mental health problems (Bragg and Atkins, 2016). Several studies have demonstrated the physical, social and psychological benefits of these nature-based activities, such as improvements in mood (Hewitt *et al*., 2013), self-esteem and social interaction (Sempik *et al*., 2014), and reductions in stress (Adevi and Maartensson, 2013), anxiety and depression (Sahlin *et al*., 2015).

One pathway liking natural environments with mental health and wellbeing can broadly be termed psychological restoration. This has been explained by two theories: Stress Reduction Theory (SRT: Ulrich *et al*., 1991) and Attention Restoration Theory (ART: Kaplan, 1995), each of which identifies a particular process of restoration (Markevych *et al*., 2017). Ulrich's SRT focuses on the promotion of psycho-physiological stress reduction on the basis that natural stimuli can rapidly evoke positive emotions and reduce levels of physiological arousal and negative thoughts, thereby enhancing recovery from stress. In contrast, Kaplan's ART is concerned with the restoration of a functional capability. ART suggests that natural environments can restore limited cognitive resource (i.e. attention) that becomes depleted with overuse. This can be achieved when the human-environment relationship has met four qualities: being away, fascination, extent, and compatibility (Kaplan, 1995). Both SRT and ART have been supported by experimental studies reporting that experiencing natural environments results in better restorative outcomes compared with more synthetic built outdoor or indoor environments. For example, Gidlow *et al.* (2016) found walking in a natural environment had greater restorative benefits compared to walking in a built environment. An experimental study by Ewert and Chang (2018) also found that visitors to natural environments had a significant reduction in both physical and psychological stress levels after the visit, as opposed to those who visited a more built-up outdoor setting or indoor sports centre. A growing body of evidence also testifies to the benefits of engaging with nature in terms of supporting personal identity and feeling part of something bigger than oneself e.g. Birch *et al*. (2020) found urban natural environments had potential to provide young people with a non-judgemental space of "*connection and care with the human and non-human world*".

Feeling of nature connectedness

A feeling of connection with nature or 'nature connectedness' is often defined as "*the affective, cognitive, and experiential relationship individuals have with the natural world or a subjective sense of connectedness with nature*" (Nisbet *et al*., 2009, p.719). Previous studies have showed that people who visit natural environments more frequently report a greater feeling of connection to nature (Richardson and Sheffield, 2017). People who are connected to nature derive a feeling of meaningful involvement from that connection, leading to positive mental health and wellbeing (Howell *et al*., 2013). The experience of wellbeing is described by two approaches: hedonic wellbeing emphasises the emotions of pleasure, defined as the absence of negative feelings and presence of positive feelings, whereas eudaimonic wellbeing focuses on living life in a purposeful way (Deci and Ryan, 2008; McMahan and Estes, 2011). Several studies have shown that a stronger connection with nature is associated with greater hedonic wellbeing, such as happiness (Mayer *et al*., 2009; Nisbet *et al*., 2011a) and life satisfaction (Mayer *et al*., 2009). At the same time, a feeling of connection with nature is related positively to the eudaimonic aspect of wellbeing by regulating emotion and imbuing people with purpose and meaning in life by giving them the feeling that they belong to the natural world (Trigwell *et al*., 2014; Cleary *et al*., 2017). On a similar note, Nisbet *et al*. (2011) also highlighted that an individual's nature connectedness is linked to their sense of purpose, self-determination and personal development. Cervinka *et al*. (2012) also demonstrated similar findings in which nature connectedness is strongly connected to sense of purpose. Furthermore, evidence suggests that eudaimonic wellbeing outcomes likely sustain in the long-term, whereas hedonic wellbeing derived from the experience of simple pleasures likely dissipates after a short period of time (Steger *et al*., 2008). Thus, it seems that *'nature connectedness'* may support the benefits of wellbeing interventions such as MBSR so that they last longer when carried out in natural environments.

Mindfulness-based stress reduction (MBSR)

Mindfulness practice has grown quickly in recent years as one of the most promising psychological interventions for those coping with common mental health problems (Spijkerman *et al*., 2016). In contrast to cognitive behavioural therapies, mindfulness-based approaches do not target psychopathology per se; like other complementary therapies, MBSR attempts to alleviate the suffering that is part of everyday life (Kabat-Zinn, 1982). Mindfulness refers to a way of focusing on experiences in the present moment without attempts at labelling or judging, which derives from Eastern contemplative traditions (Kabat-Zinn, 1982; Bishop *et al*., 2004). Mindfulness practice leads to non-judgmental acceptance of all experience, which in turn results in an increase in emotional balance and psychological wellbeing (Baer, 2003). The potential salutogenic benefits of mindfulness have led to the development of standardised mindfulness-based interventions (MBIs), which combine the principle of traditional meditation practice with psychoeducational training in order to improve health and wellbeing (Gu *et al*., 2015).

The most widely used MBI is mindfulness-based stress reduction (MBSR: Kabat-Zinn, 1982) which offers an intensive 8-week programme involving a range of mindfulness practices - formal sitting and walking meditation, body scanning and mindful movement exercises- combining daily practice at home and an all-day intensive mindfulness meditation retreat (Kabat-Zinn, 1982). The premise of MBSR is that with repeated training in mindfulness practice, individuals will eventually be more able to deal with their stress and negative thoughts (Keng *et al*., 2011; Mindfulness Initiative, 2015). Evidence of the effectiveness of MBSR indicates positive health and wellbeing outcomes, the improvement of cognitive performance (Lao *et al*., 2016), stress reduction (Song and Lindquist, 2015; Simpson *et al*., 2017) and relief from emotional distress (Bränström *et al*., 2010; Lengacher *et al*., 2014), depression (Song and Lindquist, 2015), and anxiety (Vøllestad *et al*., 2011; Song and Lindquist, 2015). However, the time commitment is substantial. Most people do not have the time or resources needed to participate in extensive meditation programmes. Different formats therefore have to be considered in order to match the needs of particular user groups (e.g. full time workers or students) and recently brief MBSR has been introduced to overcome the time and schedule requirements of these user groups (Gilmartin *et al.*, 2017). A number of studies have noted the effect of such brief MBSR (≤ less than 5-week) on improvements in mindfulness and psychological wellbeing (Mackenzie *et al*., 2006; Josefsson *et al*., 2014). While much evidence shows the significant mental health and wellbeing benefits of MBSR, there are only a few studies that have investigated the effect of combining mindfulness practice with other restorative experiences, such as exposure to nature (e.g. Kaplan, 2001; Lymeus *et al*., 2017). In order to contribute to this growing area of research, this study examined the enhancement of a common wellbeing intervention through participants' exposure to natural environments via its experimental, factorial design (i.e. one natural outdoor, one built outdoor and one indoor environment) and the multiple outcome measures.

Aim and hypotheses

The aim of the present study is to investigate whether the impacts of a commonly used wellbeing intervention (i.e. MBSR) are enhanced when combined with a natural environment. We hypothesise that MBSR in a natural environment results in greater nature connectedness than in a built outdoor or an indoor environment (hypothesis 1). It is also hypothesised that MBSR achieves the best mental health and wellbeing outcomes when conducted in a natural environment (hypothesis 2). Finally, we investigate whether the health and wellbeing outcomes of MBSR are mediated by change in nature connectedness over time (hypothesis 3).

2. Methods

2.1 Participants

The study was ethically approved by the Department of Landscape in accordance with protocols set by the University Research Ethics Committee. Participants were recruited from students and staff at the university though the university's volunteer email list. The experimental procedure was explained to potential participants in a recruitment email which required them to give their informed consent in order to be included in the study. Based on a power of 0.95 and an alpha of .05, 69 participants were calculated to be sufficient to detect a small-medium effect (f= .20). Initially, 113 students and staff agreed to participate. A sample of 99 participants, which allowed for 30% attrition, were randomly selected by stratified random sampling to ensure a representative number of male (37 male, 37.3%) and female (62 female, 62.7%) relative to the university population: natural outdoor (11 male, 22 female), built outdoor (12 male, 21 female), and indoor environment (14 male, 19 female). All participants had the opportunity to be entered into a prize draw to win one of 10 prizes of £50.

2.2 Design

The study consisted of an experiment in which participants were randomly assigned to an MBSR group in one of three different environments: natural outdoor (public park), built outdoor (courtyard on the university campus) and indoor environment (a seminar room). See Figure 1 for the schematic overview of the experimental set-up. The participants were asked to attend a brief version of the MBSR programme lasting six weeks. The intervention was a structured 6-week programme with groups of between 6 and 10 participants. Each weekly session lasted one hour and included mindfulness meditation/exercises and group discussion led by a qualified mindfulness instructor. The participants were asked to complete a questionnaire containing questions based on the following five validated scales: Five Facet Mindfulness Questionnaire (FFMQ-SF), Nature Relatedness Scale (NR-6), Positive and Negative Affect Schedule (PANAS), Rumination-Reflection Questionnaire (RRQ) and Depression Anxiety Stress Scales (DASS-21). The questionnaires were completed four times during the research period: at baseline (T0), after the third MBSR session (T1), one week after the completion of the 6-week MBSR (T2) and one month after the completion of the 6-week MBSR (T3).

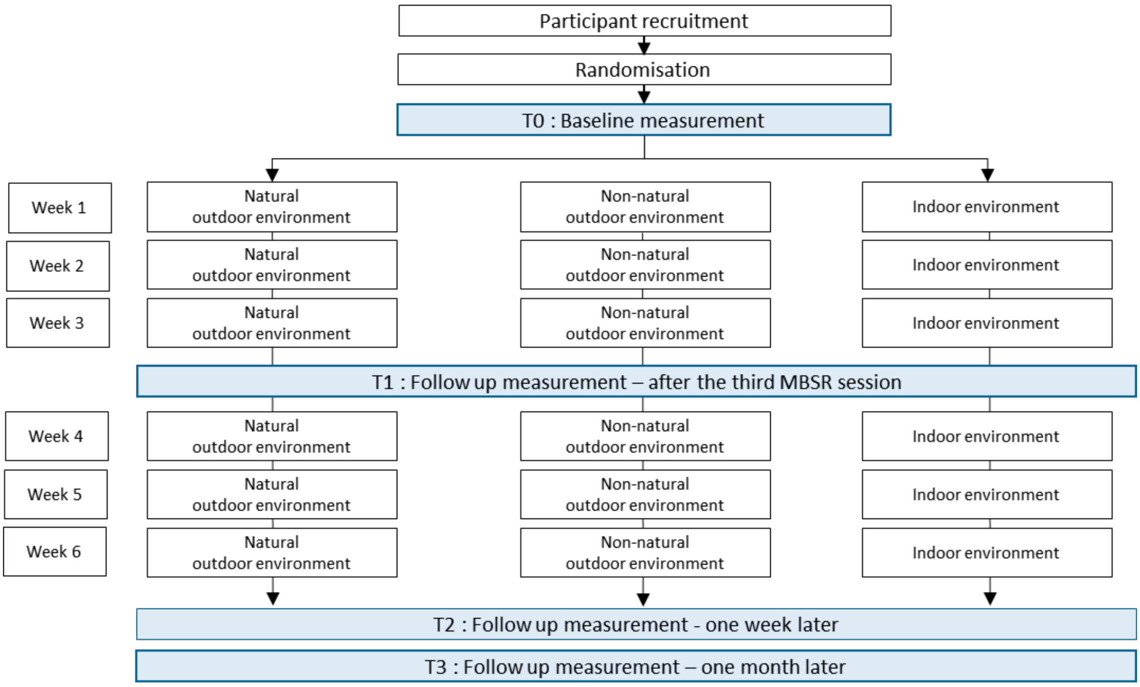

Figure 1. Research design

2.3 Environments

So that all participants had similar access to our research locations, we chose three sites for this study within a radius of 200m of the university campus: a) Weston Park, representing a natural outdoor environment, b) a courtyard on the university campus, representing a built outdoor environment, and c) a seminar room in the Octagon centre, representing an indoor environment (Figure 2). Weston Park is a public park near the university, designed in 1873 with an area of over 5 hectares. The park is a well-managed green space containing trees, shrubs, flower beds, lawns and a lake, and includes facilities such as benches, wooden bridges, a bandstand and monuments. The experiment was carried out in a location defined by planted areas containing shrubs and small trees, with some distant views. A courtyard on the university campus was chosen as a built outdoor environment. The courtyard was surrounded by concrete and brick built settings, with no visible vegetation. The indoor setting was a seminar room: a white painted room without windows in the basement of a university building. It contained chairs, a neutral coloured picture and no vegetation. Participants in all environments were exposed to full sensory experiences, such as sound (e.g. background noise) and smell.

a) Natural outdoor environment   b) Built outdoor environment   c) Indoor environment

Figure 2. Three different experimental settings

2.4 Questionnaire and measures

Psychometrically validated scales were chosen to measure the efficacy of the MBSR, and changes in the outcomes were measured during the research period. The baseline questionnaire at T0 comprised two sections containing the psychometric scales and questions eliciting personal information respectively. The latter asked participants to indicate their gender, age, ethnicity, postcode and any previous experience of mental health problems or mindfulness practice. The follow-up questionnaires at T1, T2 and T3 contained the same psychometric scales but the personal information questions were omitted.

Five Facet Mindfulness Questionnaire

The Five Facet Mindfulness Questionnaire (FFMQ-SF: Bohlmeijer *et al.*, 2011) measures respondents' levels of mindfulness and psychological symptoms. The FFMQ-SF contains 24 items measured on a five-point Likert scale, ranging from 1 (never or rarely true) to 5 (very often or always true). The five facets consist of five subscales: non-judging, non-reactivity, acting with awareness, describing and observing. In the present study, these sub-scales were summed to a total mindfulness score (e.g. Vøllestad *et al*., 2011; Goldberg *et al*., 2013). Scores ranged from 3 to 24, with higher scores indicating a greater degree of mindfulness. Our data had high internal consistency with Cronbach's alpha of 0.84.

Nature Relatedness Scale

The Nature Relatedness Scale (NR-6: Nisbet and Zelenski, 2013) measures affective, cognitive, and experiential aspects of 'connectedness to nature'. The NR-6 contains six items measured on a five-point Likert scale ranging from 1 (disagree strongly) to 5 (agree strongly). Scores ranged from 1 to 5 with higher scores indicating a stronger relationship with nature. Data had high internal consistency with Cronbach's alpha of 0.90.

Positive and Negative Affect Schedule

The Positive and Negative Affect Schedule (PANAS: Watson *et al*., 1988) measures hedonic wellbeing, eliciting respondent's current state across a wide variety of emotions. The PANAS contains two 10-item subscales designed to measure positive feelings (i.e. interested, excited, strong, enthusiastic, proud, alert, inspired, attentive, determined and active), and negative feelings (i.e. distressed, upset, guilty, scared, hostile, irritated, ashamed, nervous, jittery and afraid). Respondents were asked how much they felt each of the 20 emotions (1= not at all, 5= extremely). Scores ranged from 10 to 50 with higher scores indicating higher levels of positive or negative feelings. Cronbach's alpha was 0.86 for the Positive affect subscale, and 0.89 for the Negative affect subscale.

Rumination-Reflection Questionnaire

The eudaimonic wellbeing outcomes were assessed using the Rumination-Reflection Questionnaire (RRQ: Trapnell and Campbell, 1999). Both rumination and reflection involve self-focusing tendencies, but they differ in self-attentive motives. The Rumination subscale measures self-attentiveness motivated by anxiety or fear (e.g. "Often I'm playing back over in my mind how I acted in a past situation"), and the Reflection subscale measures self-attentiveness motivated by a genuine curiosity (e.g. "I love analysing why I do things") (Harrington and Loffredo, 2011). The RRQ contains 24 items measured on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Scores ranged from 1 to 5 with higher scores indicating higher levels of rumination or reflection. Cronbach's alpha was 0.90 for the Rumination subscale, and 0.85 for the Reflection subscale.

Depression Anxiety Stress Scales

The Depression Anxiety Stress Scales (DASS-21) contains 21 psychological questions related to the symptoms of depression, anxiety and stress (Lovibond and Lovibond, 1995; Antony *et al.*, 1998). The DASS-21 contains three self-report subscales with seven phrases that describe how respondents felt in the past week on a four-point scale (0= never, 3= almost always): e.g. Depression ("I felt that I had nothing to look forward to"); e.g. Anxiety ("I was worried about situations in which I might panic and make a fool of myself"); and e.g. Stress ("I found it difficult to relax"). Scores ranged from 0 to 42 with higher scores indicating higher levels of depression, anxiety and stress. DASS-21 showed high internal consistency with Cronbach's alpha of 0.89 for the Depression subscale, 0.82 for the Anxiety subscale and 0.83 for the Stress subscale.

2.5 Procedure

Potential participants were emailed a web link to a participant information sheet and a baseline questionnaire (T0), which they were asked to complete before attending the experiment. Once participants had completed the questionnaire, they were randomly assigned to the MBSR programme in one of the three different environments. In its first week, participants were contacted via email with instructions which included the location of the experiment and overview of programme. However, to reduce potential bias from foreknowledge of the intervention, participants were not informed of the other groups/environments. During the experiment, participants were asked three times (T1, T2 and T3) to complete the same questionnaire which they had filled in before the experiment. The experiment was conducted over 10 weeks between August and October 2017.

2.6 Analysis strategy

An intention-to-treat (ITT) analysis (Figure 3) was performed on MBSR outcomes in which all participants were included (n=99) with drop-outs assigned a follow-up value as baseline. ITT analysis is widely used to avoid over-optimistic results of the effectiveness of an intervention resulting from the removal of non-compliers by including noncompliance, protocol deviations and withdrawal, all of which are likely to occur in actual clinical practice (Gupta, 2011). In order to ensure the findings were robust, we also used per-protocol (PP) analysis to examine MBSR outcomes in different environments. PP analysis included only those people who strictly adhered to the protocol, i.e. those who attended all of the 6-week MBSR sessions. Results from the ITT and PP analyses were very similar, so the results reported in this manuscript are those from the ITT analysis; the results of the PP analysis can be found in Supplementary File 1.

All analysis was conducted using SPSS for Windows version 24.0 using an alpha of .05. We also report effect sizes; Cohen (1988) suggests η^2= .01 is small, η^2= .06 medium and η^2= .14 large. Firstly, χ^2 tests and ANOVA were used to examine differences at baseline. Next, MANOVA was used to investigate the effects of the intervention in the three different environments. These analyses incorporated a between-subjects factor (natural outdoor, built outdoor and indoor environment) and four time-points of interventions (T0, T1, T2 and T3) for mental health and wellbeing outcomes. If there was a significant interaction, follow-up analysis was performed using one-way ANOVAs to compare environments, and where environment was significant, this was explored using post-hoc comparisons with Tukey's HSD. Paired samples t-tests were also used to further investigate the impact of MBSR in each group. Finally, in order to understand possible interactions and explore pathways of enhancement of MBSR outcomes by nature connectedness, the indirect effect of changes in nature connectedness on the interventions' wellbeing outcomes were examined by path analysis using the Process macro for SPSS (Hayes, 2012).

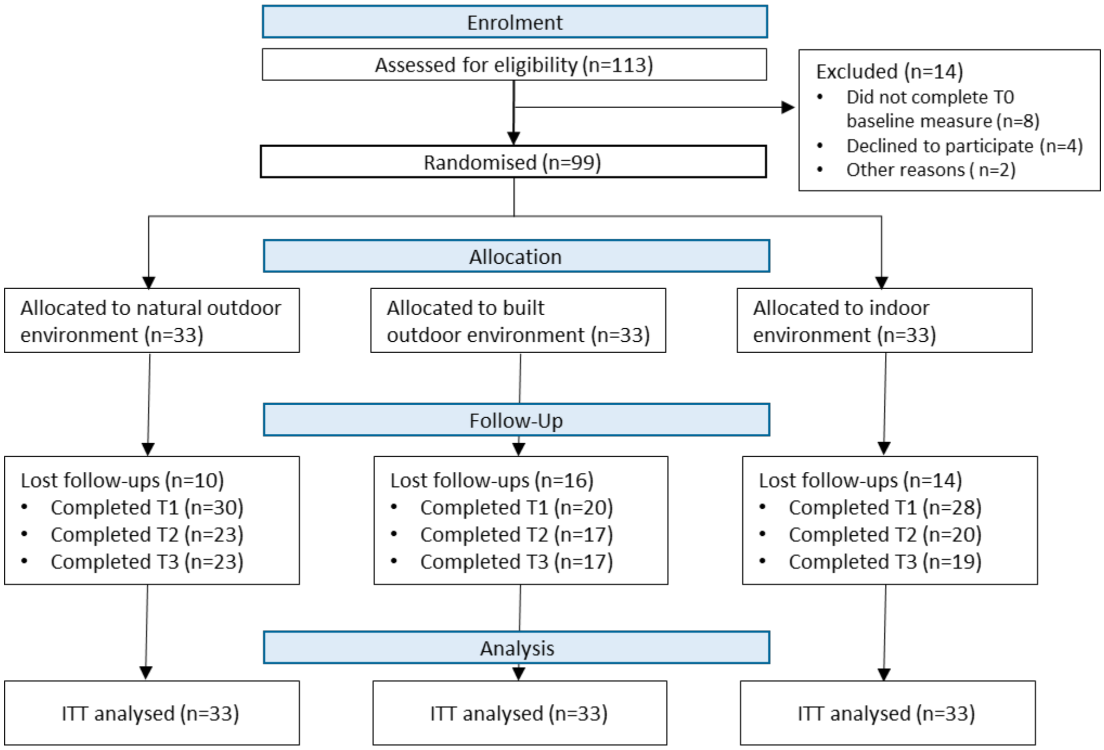

Figure 3. CONSORT flow chart

3. Results

Given that the effects of MBSR have been shown to differ according to age and gender, demographic, baseline data were examined (e.g. Katz and Toner, 2013). A total of 99 participants was eligible for analysis (37 male and 62 female; mean age 36.35; range 16-62 years). It is worth mentioning in this stage, out of the three cohorts in Figure 3, the natural outdoor environment cohort is the one that showed the greatest adherence across the experiment. No significant differences in age (χ^2= 80.20, p= .19) and gender (χ^2=0.09, p= .96) were found between the experimental conditions. Univariate ANOVAs revealed no baseline differences in any of the study measures by environment, p> .05.

Next, MANOVA was used to examine the main effects of time and environments on all measures. An initial MANOVA that included gender revealed no gender interactions in the multivariate or univariate effects, all $p > .05$. It revealed the main effect of time was significant, $F(27,70) = 4.41$, $p < .001$, $\eta^2 = .63$, indicating that measures changed over time. There were also significant interactions between the three environments (natural outdoor, built outdoor and indoor environment) and the four time points (T0, T1, T2 and T3), $F(54,140) = 1.44$, $p = .046$, $\eta^2 = .36$, at the multivariate level, indicating that changes in the MBSR outcomes over time were different in the environments. Table 1 shows the means, standard deviations and confidence intervals for all measurements by environment at the four time-points.

Table 1 Mean scores (and standard deviation) on questionnaires at four time points

Outcome	**T0** M(SD) [95%CI*]	**T1** M(SD) [95%CI*]	**T2** M(SD) [95%CI*]	**T3** M(SD) [95%CI*]
FFMQ-SF: Mindfulness				
Natural outdoor environment	15.85(2.62) [14.92;16.78]	16.36(1.80) [15.72;16.99]	16.62(2.52) [15.72;17.51]	16.80(2.50) [15.92;17.69]
Built outdoor environment	16.74(2.74) [15.77;17.71]	16.52(2.49) [15.63;17.40]	16.29(1.60) [15.72;16.85]	16.90(2.47) [16.02;17.77]
Indoor environment	15.50(2.74) [14.53;16.47]	15.26(2.21) [14.48;16.04]	15.63(2.10) [14.89;16.38]	15.64(2.24) [14.85;16.44]
NR-6: Nature connectedness				
Natural outdoor environment	3.38(0.89) [3.06;3.70]	3.79(0.82) [3.50;4.08]	3.78(0.91) [3.46;4.11]	3.79(0.92) [3.46;4.11]
Built outdoor environment	3.42(0.96) [3.08;3.76]	3.52(0.79) [3.25;3.81]	3.55(0.74) [3.28;3.80]	3.51(0.83) [3.22;3.80]
Indoor environment	3.35(0.75) [3.09;3.62]	3.39(0.73) [3.13;3.65]	3.48(0.80) [3.20;3.77]	3.39(0.85) [3.08;3.69]
PANAS: Positive affect				
Natural outdoor environment	30.55(6.94) [28.09;33.01]	31.73(7.95) [28.91;34.54]	33.24(7.99) [30.41;36.07]	33.70(8.05) [30.84;36.55]
Built outdoor environment	29.15(5.85) [27.08;31.23]	29.82(6.76) [27.42;32.12]	30.21(5.99) [28.09;32.34]	30.12(6.69) [27.75;32.49]
Indoor environment	32.00(6.20) [29.80;34.20]	33.12(7.11) [30.60;35.64]	32.61(6.77) [30.20;35.01]	33.21(6.21) [31.01;35.42]
PANAS: Negative affect				
Natural outdoor environment	25.48(8.58) [22.44;28.53]	21.97(6.79) [19.56;24.38]	20.03(6.95) [17.56;22.50]	20.12(6.85) [17.69;22.55]
Built outdoor environment	24.36(8.90) [21.21;27.57]	22.79(8.49) [19.78;25.80]	23.03(8.54) [20.00;26.06]	22.85(9.04) [19.64;26.05]
Indoor environment	25.91(7.90) [23.11;28.71]	22.39(7.01) [19.91;24.88]	21.52(5.05) [19.72;23.31]	21.76(5.53) [19.80;23.72]
RRQ: Rumination				

Natural outdoor environment	3.71(0.83) [3.42;4.00]	3.42(0.65) [3.19;3.66]	3.03(0.67) [2.79;3.26]	2.92(0.53) [2.73;3.10]
Built outdoor environment	3.65(0.73) [3.39;3.91]	3.51(0.68) [3.27;3.75]	3.43(0.60) [3.22;3.65]	3.44(0.61) [3.23;3.66]
Indoor environment	3.63(0.80) [3.35;3.91]	3.39(0.84) [3.10;3.69]	3.31(0.70) [3.06;3.56]	3.29(0.68) [3.04;3.53]
RRQ: Reflection				
Natural outdoor environment	3.23(0.71) [2.98;3.48]	3.66(0.57) [3.46;3.86]	3.66(0.60) [3.44;3.87]	3.65(0.72) [3.39;3.90]
Built outdoor environment	3.47(0.75) [3.21;3.74]	3.52(0.66) [3.29;3.76]	3.56(0.70) [3.31;3.81]	3.57(0.67) [3.32;3.80]
Indoor environment	3.43(0.78) [3.16;3.71]	3.46(0.65) [3.23;3.69]	3.48(0.65) [3.26;3.71]	3.44(0.77) [3.17;3.72]
DASS-21: Depression				
Natural outdoor environment	10.73(8.24) [7.80;13.65]	7.94(7.48) [5.29;10.59]	6.79(6.78) [4.38;9.19]	6.55(6.86) [4.11;8.98]
Built outdoor environment	10.24(7.51) [7.85;12.91]	9.27(7.19) [6.72;11.92]	7.94(6.28) [5.71;10.16]	8.06(6.72) [5.68;10.44]
Indoor environment	9.45(8.10) [6.58;12.33]	7.15(6.33) [4.91;9.39]	6.70(6.87) [4.26;9.13]	6.73(7.98) [3.90;9.56]
DASS -21: Anxiety				
Natural outdoor environment	9.39(7.37) [6.78;12.01]	8.06(6.59) [5.73;10.40]	6.61(6.74) [4.22;8.99]	5.94(7.06) [3.44;8.44]
Built outdoor environment	7.88(6.18) [5.69;10.07]	7.70(4.10) [6.24;9.15]	6.52(3.84) [5.15;7.88]	6.79(5.98) [4.67;8.91]
Indoor environment	9.24(9.09) [6.02;12.47]	6.91(7.02) [4.42;9.40]	6.30(5.86) [4.23;8.38]	6.12(6.32) [3.88;8.36]
DASS-21: Stress				
Natural outdoor environment	16.61(8.05) [13.75;19.46]	11.94(5.91) [9.85;14.03]	10.48(6.98) [8.01;12.96]	9.82(6.21) [7.62;12.02]
Built outdoor environment	15.27(7.71) [12.54;18.01]	15.09(6.93) [12.63;17.55]	15.36(8.14) [12.48;18.25]	14.70(8.93) [11.53;17.86]
Indoor environment	15.12(10.02) [11.57;18.67]	12.79(7.31) [10.19;15.38]	11.58(6.08) [9.42;13.73]	12.85(6.37) [10.59;15.11]

*CI: Confidence Interval

3.1 Level of mindfulness

A time by environment repeated measures ANOVA revealed a main effect of time on mindfulness, $F(3,94) = 2.93$, $p = .04$, $\eta^2 = .09$; there was a significant increase through the research period. However, there was no statistically significant interaction between time and environment, $F(6,188) = 0.86$, $p = .51$, $\eta^2 = .03$. As shown in Figure 4, no significant differences were found between environments across the time points.

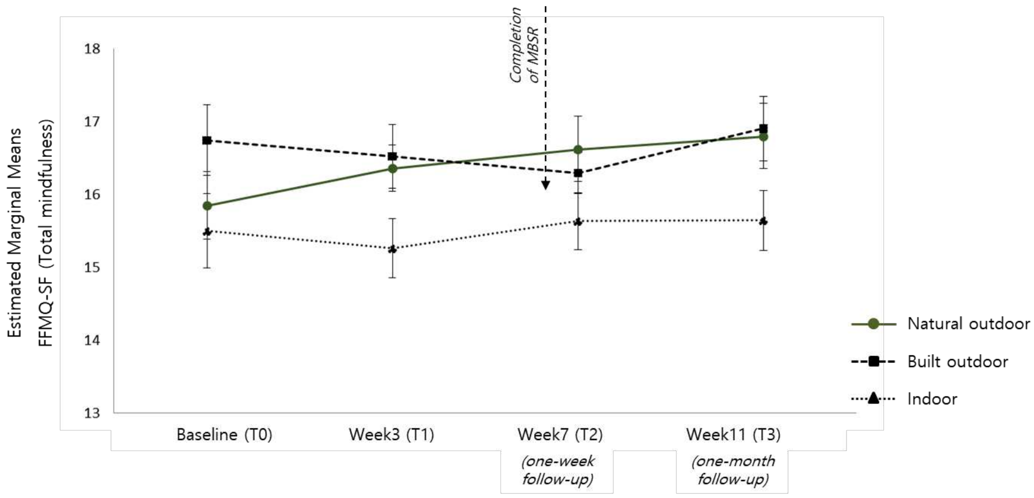

Figure 4. Interaction graph for mindfulness; Error bars represent 95% confidence intervals.

3.2 Nature connectedness

Time had a statistically significant effect on nature connectedness, $F(3,94)= 6.89$, $p< .001$, $\eta^2= .18$. A significant interaction effect was found between time and environment, $F(6,188)= 2.74$, $p= .01$, $\eta^2= .08$. ANOVA revealed no significant differences between the environments at each time point, $p> .05$. Paired samples t-tests were used to investigate further the impact of MBSR in each group. In the natural outdoor environment, there was a statistically significant increase in nature connectedness from T0 (M=3.38, SD=0.89) to T3 (M= 3.79, SD= 0.92), t(32)= -3.41, $p= .002$, $\eta^2= .27$. However, no significant differences were found in the built outdoor environment from T0 (M= 3.42, SD= 0.96) to T3 (M= 3.51, SD= 0.83), t(32)= -1.15, $p= .26$, $\eta^2= .04$. Similarly, in the indoor environment, t-tests revealed no significant difference in nature connectedness from T0 (M= 3.35, SD= 0.75) to T3 (M= 3.39, SD= 0.85), t(32)= -0.40, $p= .70$, $\eta^2= .00$. Thus, nature connectedness was improved only in the MBSR group in the natural outdoor environment, not in the other environments (Figure 5).

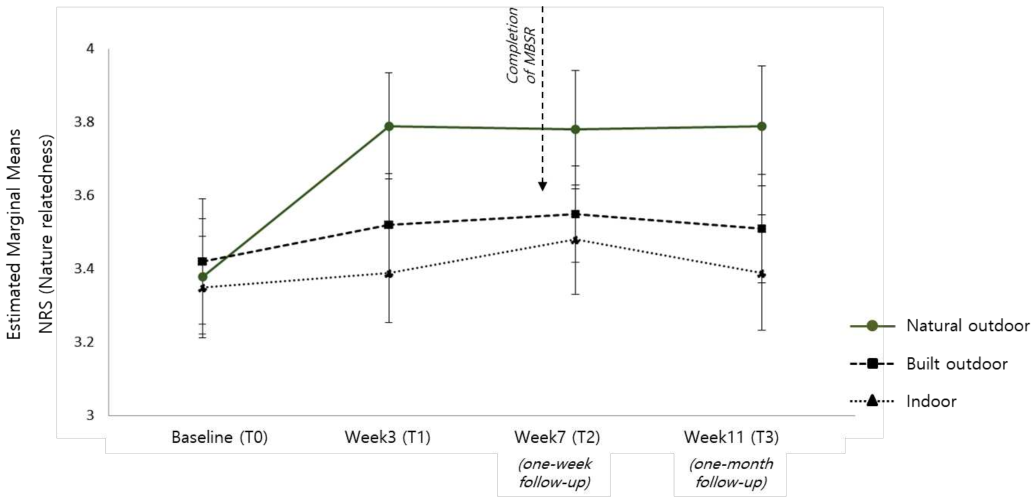

Figure 5. Interaction graph for nature connectedness; Error bars represent 95% confidence intervals.

3.3 Positive and negative affect

Positive Affect

A time by environment repeated measures ANOVA revealed that time had a significant effect on positive affect, $F(3,94)= 2.70$, $p= .049$, $\eta^2= .08$. However, there was no significant time by environment interaction, $F(6,188)= 0.82$, $p= .55$, $\eta^2= .03$. As shown in Figure 6, no significant differences were found between environments, $p> .05$.

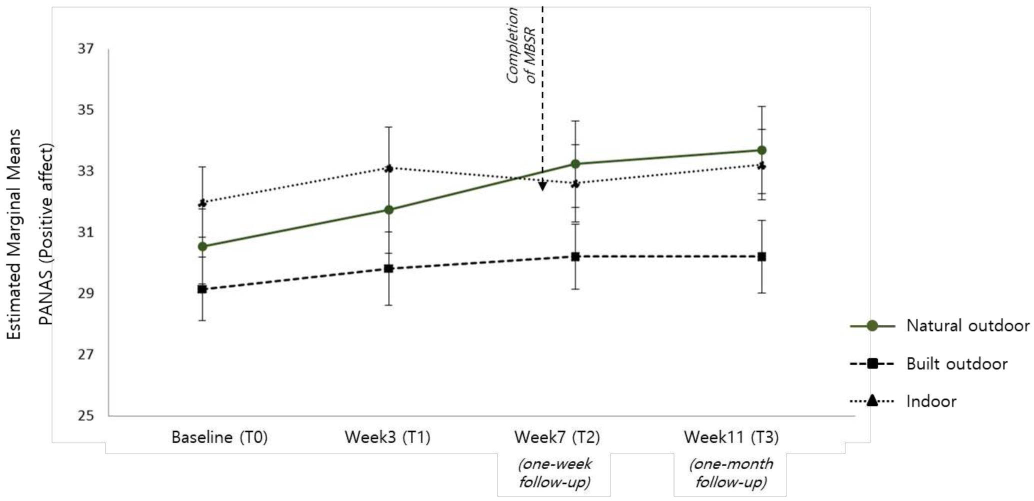

Figure 6. Interaction graph for positive affect; Error bars represent 95% confidence intervals.

Negative Affect

Time had a statistically significant impact on negative affect, $F(3,94)= 10.27$, $p< .001$, $\eta^2= .25$. Although there was no statistically significant interaction between time and environment, $F(6,188)= 1.18$, $p= .32$, $\eta^2= .04$, Figure 7 suggests that the biggest drop of negative affect occurred in the natural outdoor environment.

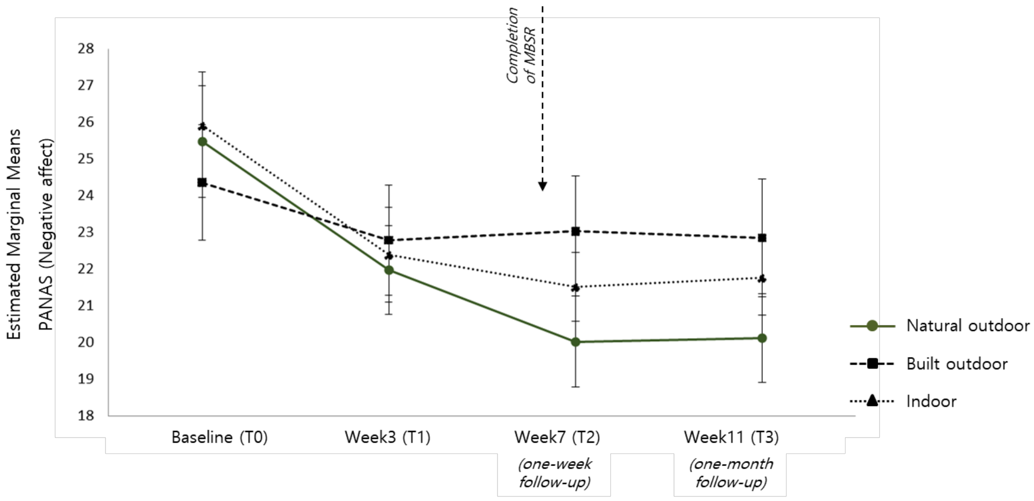

Figure 7. Interaction graph for negative affect; Error bars represent 95% confidence intervals.

3.4 Rumination and reflection

Rumination

A time by environment repeated measures ANOVA revealed a main effect of time on rumination scores, $F(3,94)= 17.11$, $p< .001$, $\eta^2= .35$. There was also a significant interaction effect between time and environment, $F(6,188)= 3.23$, $p= .01$, $\eta^2= .09$. ANOVA revealed no differences between environments at T0, $F(2,96)= 0.09$, $p= .91$, $\eta^2= .00$, and at T1, $F(2,96)= 0.21$, $p= .81$, $\eta^2= .00$. However, the difference in participants' level of rumination between groups was significant at T2, $F(2,96)= 3.37$, $p= .04$, $\eta^2= .07$, and at T3, $F(2,96)= 6.42$, $p= .002$, $\eta^2= .12$. The decrease in rumination persisted at the follow-ups (T2 and T3) in the natural outdoor environment, but not in the other environments. Our post-hoc test indicated that the mean score for the natural outdoor group (M= 2.92, SD= 0.53) was significantly different from both the groups in the built outdoor (M= 3.44, SD= 0.61) and indoor environments (M= 3.29, SD= 0.68); the group in the built environment did not differ significantly from the indoor group at T3. Paired samples t-tests were conducted to investigate further the impact of MBSR in each group. In the natural outdoor environment, there was a statistically significant decrease in rumination from T0 (M= 3.71, SD= 0.83) to T3 (M= 2.92, SD= 0.53), t(32)= 6.16, *p*< .001, η^2= .54. A significant decrease was also found in the built outdoor environment from T0 (M= 3.65, SD= 0.73) to T3 (M= 3.44, SD= 0.61), t(32)= 2.44, *p*= .02, η^2= .16. Similarly, in the indoor environment, t-tests revealed a significant decrease in rumination from T0 (M= 3.62, SD= 0.80) to T3 (M= 3.29, SD= 0.68), t(32)= 3.09, *p*= .004, η^2= .23. Thus, all three groups showed a significant decrease in rumination, but the improvement in the natural outdoor environment was greater than in the other environments (Figure 8).

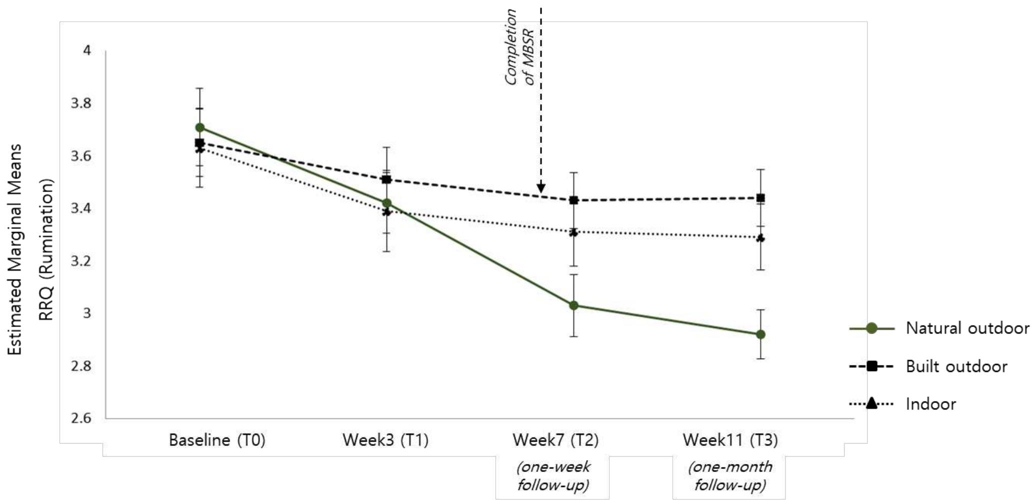

Figure 8. Interaction graph for rumination; Error bars represent 95% confidence intervals.

Reflection

Time had a statistically significant effect on reflection, *F*(3,94)= 4.53, *p*= .01, η^2= .13. There was also a significant time by environment interaction, *F*(6,188)= 2.31, *p*= .04, η^2= .07. However, subsequent ANOVAs revealed no significant differences between the environments at each time point, *p*> .05. We also conducted Paired samples t-tests to investigate the impact of MBSR in each group. In the natural outdoor environment, there was a statistically significant increase in reflection from T0 (M=3.23, SD=0.71) to T3 (M= 3.65, SD= 0.72), t(32)= -2.77, p= .01, η^2= .19. However, no significant difference was found in the built outdoor environment from T0 (M= 3.47, SD= 0.75) to T3 (M= 3.56, SD= 0.67), t(32)= -1.35, p= .19, η^2= .05. In the indoor environment group, t-tests also revealed no significant difference in reflection from T0 (M= 3.43, SD= 0.78) to T3 (M= 3.44, SD= 0.77), t(32)= -0.08, p= .94, η^2= .00. Thus, the natural outdoor environment group had greater improvement in reflection than the groups in the other environments (Figure 9).

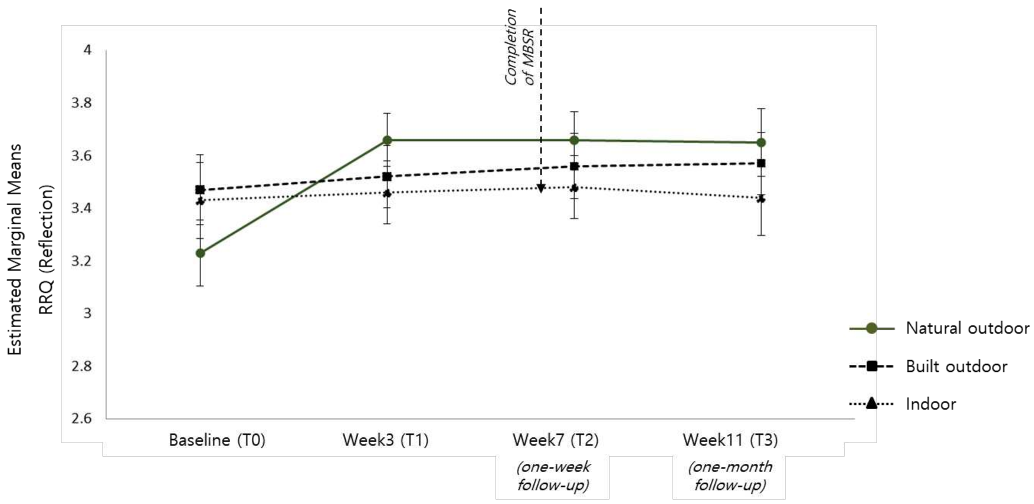

Figure 9. Interaction graph for reflection; Error bars represent 95% confidence intervals.

3.5 Depression, anxiety and stress

Depression

A time by environment repeated measures ANOVA revealed that time had a significant effect on depression, $F(3,94)= 7.99$, $p< .001$, $\eta^2= .20$. However, there was no significant time by environment interaction, $F(6,188)=0.48$, $p= .83$, $\eta^2= .02$. As shown in Figure 10, all the groups' level of depression decreased over time and there were no significant differences between environments.

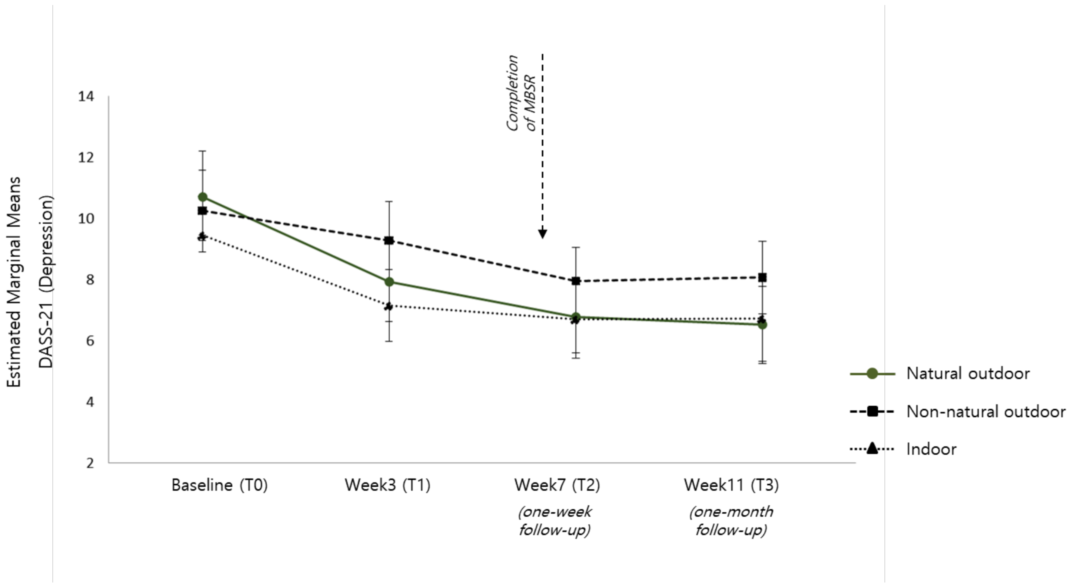

Figure 10. Interaction graph for the depression; Error bars represent 95% confidence intervals.

Anxiety

Time had a significant effect on anxiety, $F(3,94)= 7.45$, $p< .001$, $\eta^2= .19$; there was a significant decrease through the study. However, there was no statistically significant interaction between time and environment, $F(6,188)= 0.97$, $p= .45$, $\eta^2= .03$. As shown in Figure 11, no significant differences were found between environments.

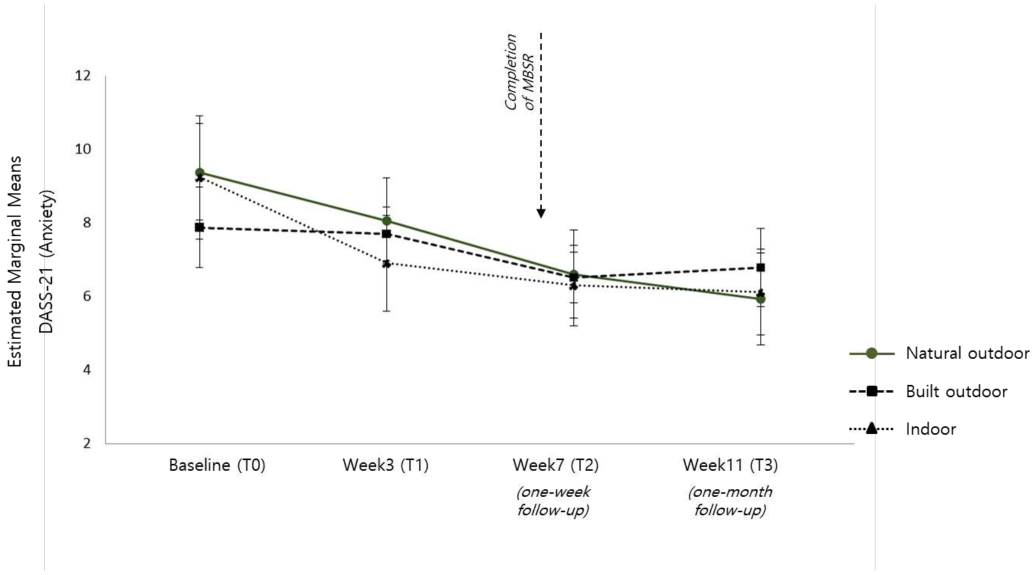

Figure 11. Interaction graph for anxiety; Error bars represent 95% confidence intervals.

Stress

Time had a statistically significant impact on stress, $F(3,94)= 5.52$, $p= .002$, $\eta^2= .15$. There was also a significant time by environment interaction, $F(6,188)= 2.446$, $p=.03$, $\eta^2= .07$. ANOVA revealed no differences between the environments at T0, $F(2,96)= 0.35$, $p= .71$, $\eta^2= .01$, and at T1, $F(2,96)= 1.93$, $p= .15$, $\eta^2= .04$, at T2, $F(2,96)= 2.69$, $p= .07$, $\eta^2= .05$. However, there was a significant difference at T3, when the natural outdoor environment group showed greater stress reduction than the groups in the other environments, $F(2,96) = 3.78$, $p= .03$, $\eta^2= .07$. Our post-hoc test indicated that the mean score for the natural outdoor group (M= 9.82, SD= 6.21) was significantly different from the group in the built outdoor environment (M= 14.70, SD= 8.93); the indoor group (M= 12.85, SD= 6.37) did not differ significantly from either of the groups in the natural outdoor or the built outdoor environments at T3. As shown in Figure 12, there was a steady decrease in stress in the natural outdoor environment, unlike in built outdoor and indoor environments. Paired samples t-tests were used to further investigate the impact of MBSR in each group. In the natural outdoor environment, there was a statistically significant decrease in stress from

T0 (M=16.61, SD=8.05) to T3 (M= 9.82, SD= 6.21), t(32)= 5.42, $p < .001$, $\eta^2 = .94$. However, no significant differences were found in the built outdoor environment from T0 (M= 15.27, SD= 7.71) to T3 (M= 14.70, SD= 8.93), t(32)= 0.37, $p = .71$, $\eta^2 = .00$. In the indoor environment, t-tests also revealed no significant difference in stress from T0 (M= 15.12, SD= 10.02) to T3 (M= 12.85, SD= 6.37), t(32)= 1.79, $p = .08$, $\eta^2 = .05$. Thus, the MBSR in the natural outdoor environment resulted in greater decreases in stress than in the other environments.

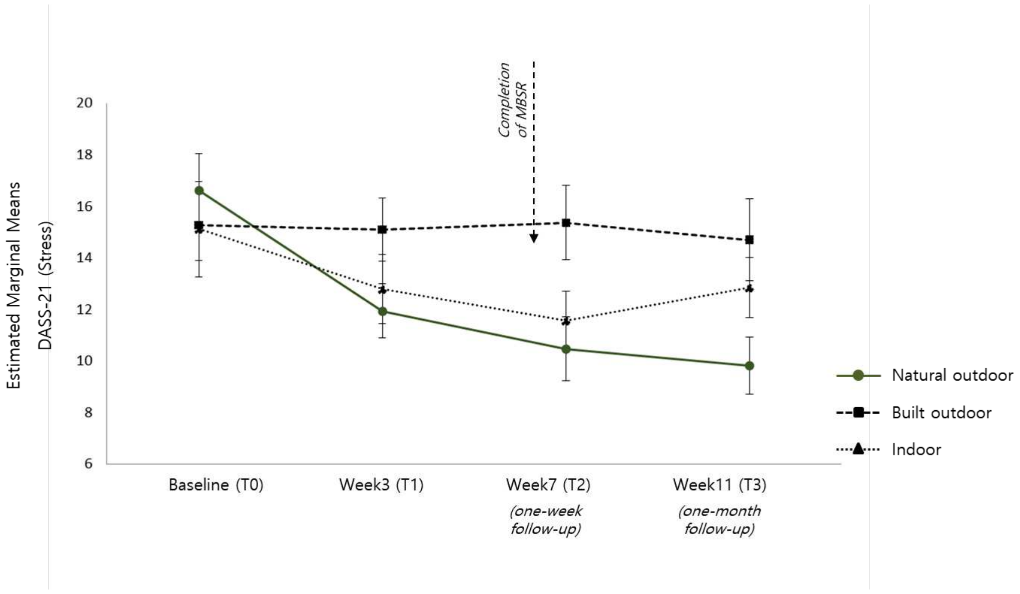

Figure 12. Interaction graph for the stress; Error bars represent 95% confidence intervals.

3.6 Summary of findings

As shown in Table 2, this study found that participants in all three groups experienced significant changes in mental health and wellbeing outcomes during the intervention. There was a significant 2-way interaction of time and environment; the changes over time of participants' levels of nature connectedness, rumination and reflection and stress were affected by environments (natural outdoor vs. built outdoor vs. indoor). However, the results of further analysis showed that only participants in the MBSR programme in the natural outdoor environment had improved nature connectedness, ruminative and reflective attitudes as well as experiencing stress reduction over the course of the intervention (including one-month follow-up).

Table 2 All main and interaction effects including the results of further analysis

Measure	Effects		Results of further analysis (one-way ANOVA/T-test)
	Time	Time x Environment	Significant difference between environments
FFMQ-SF - Mindfulness	√	-	-
NR-6 – Nature connectedness	√	√	Significant improvement only in a natural environment (T0-T3)
PANAS - Positive affect	√	-	-
PANAS - Negative affect	√	-	-
RRQ - Rumination	√	√	Significant improvement only in a natural environment (T2-T3)
RRQ - Reflection	√	√	Significant improvement only in a natural environment (T0-T3)
DASS-21 - Depression	√	-	-
DASS-21 – Anxiety	√	-	-
DASS-21 – Stress	√	√	Significant improvement only in a natural environment (T0-T3)

Note: baseline (T0), after the third MBSR session (T1), one week after the completion of the 6-week MBSR (T2), and one month after the completion of the 6-week MBSR (T3)

3.7 Potential pathway: is nature connectedness a pathway through which the interventions affect mental health and wellbeing?

We hypothesised that change in nature connectedness (calculated as T3 minus T0) would affect changes in mental health and wellbeing outcomes of MBSR. As previously indicated, the results of a time by environment interaction analysis showed that the changes over time of participants' levels of nature connectedness, rumination and reflection and stress were affected by environments. Thus, path analyses focused on the outcomes that showed significant changes by environment over time (i.e. rumination, reflection and stress).

The path analysis showed that there was no significant effect of environment manipulation on rumination through nature connectedness, *b*=0.001 (SE=0.05), 95% CI [-0.11;0.09]. However, there was a significant effect of environment manipulation on reflection through nature connectedness, *b*=-0.21 (SE=0.10), 95% CI [-0.44;-0.05]. Lastly, there was no significant indirect effect of environment manipulation on stress through nature connectedness, *b*=0.001 (SE=0.05), 95% CI [-0.11;0.09]. Accordingly, change in nature connectedness mediated the intervention's effects on reflection. In Supplementary File 2, we provide more details of path analysis results to support our findings in this manuscript.

4. Discussion

This study found that attending an MBSR programme in a natural environment results in greater nature connectedness than in a built outdoor or an indoor environment (hypothesis 1). This confirms that nature connectedness was stronger after experiencing natural environments in contrast to urban built environments (Mayer and Frantz, 2004; Nisbet and Zelenski, 2011). This is to be expected, given that people feel closer and more connected to nature when more frequently exposed to natural environments (Hinds and Sparks, 2008; Richardson and Sheffield, 2017). This finding provides primary evidence for the mediation effect of nature connectedness on the MBSR outcomes.

We also hypothesised that the MBSR programme would achieve the best mental health and wellbeing outcomes when conducted in a natural environment (hypothesis 2). Our findings partly support this hypothesis. Firstly, we found that conducting MBSR in natural environments had more positive effects on stress relief compared to the other environments (i.e. built outdoor and indoor). This result is consistent with those of Beil and Hanes (2013), who showed that a visit to natural environments in an urban area can help relaxation and stress reduction. Similarly, Tyrväinen *et al.* (2014) also found that visits to urban green environments helped to reduce stress and enhance psychological recovery compared with visits to built-up environments. Secondly, we found that attending the MBSR programme in the natural outdoor environment resulted in less rumination and more reflective attitudes - aspects of eudaimonic wellbeing - compared with the other environments. However, we did not find significant effects of the different environments on the hedonic aspects of wellbeing, such as positive or negative feelings. These results further support the ideas of Capaldi *et al*. (2014) and Trigwell *et al*. (2014) that being physically or psychologically connected with nature involves a sense of meaningful co-existence with something larger than oneself; this is strongly related to eudaimonic wellbeing e.g. feelings of meaningful/worthwhile life. Thirdly, the effects of MBSR lasted longer when conducted in the natural outdoor environment. Most of the participants in all environmental conditions showed improvements in mental health and wellbeing during the 6-week experiment. However, there were significant differences between environments at one-month follow-up (after participants had returned to their ordinary routine). For example, all participants' rumination levels decreased during the 6-week experiment, but the participants in the built outdoor and the indoor environments showed no change in rumination levels between follow-ups (T2-T3), whereas the group in the natural outdoor environment continued to improve even after the experiment. The longevity of the positive effects following MBSR in the natural environment may be explained by the eudaimonic-promoting aspects of nature connectedness, leading to sustained outcomes (McMahan and Estes, 2011).

In order to examine the effect of nature connectedness on the MBSR outcomes in this study, we tested whether the change in nature connectedness (T0-T3) mediates the effectiveness of MBSR in different environments on mental health and wellbeing (hypothesis 3). We found that the change in nature connectedness mediated the changes in participants' levels of reflection. Wolsko and Lindberg (2013) showed that individuals who have stronger feelings of nature connectedness also displayed greater trait mindfulness and psychological wellbeing. More recently, Van Gordon *et al*. (2018) outlined a reciprocal relationship between mindfulness and nature: mindful awareness can be used to enhance the restorative qualities of nature, and natural environments can support the achievement of mindfulness practice. Further research might explore the role of natural environments in existing interventions aiming to support mental health and wellbeing, and identify pathways for the mental health and wellbeing outcomes of health interventions in natural environments. This would not only help to develop the health interventions that maximize the health and wellbeing benefit uplift derived from natural environments, but also to reduce the cost of development of new health interventions by more effective use of existing resources.

Some limitations are acknowledged. First, the sample of participants could be considered as a limitation. We used ITT analysis to examine the efficacy of MBSR in different environments. However, only 56% of our sample (59 participants) completed all six MBSR sessions. To generalise and make more robust the results of this study, further research is needed with larger numbers of participants completing the programme. Although there was no gender difference in the MBSR outcomes in the current study, nor did the benefits appear different by gender, it would be interesting to explore gender differences in a similar intervention in a further larger study that recruited similar numbers of men and women. Secondly, extra mindfulness practice or previous experience of mindfulness could have made a difference to the impacts of MBSR, but this study did not control whether participants practised mindfulness outside of the formal sessions. Another concern with field experiments is that the results could be affected by weather conditions, such as heavy rain or strong winds (Bell *et al*., 2019). This study was conducted during relatively stable weather in August-October, but the weather conditions varied during the research period. In addition, in the case of the outdoor environments (natural and built), self-consciousness related to being in a public setting could be another factor affecting the results of this study. During the sessions, some participants might have felt that they were being observed by others. In future investigations, a better understanding of how to take the therapeutic intervention into the outdoors needs to be developed. Lastly, it was not feasible to explore a wider range of environments in this study. Whilst previous work has investigated broad landscape type, there is considerable scope for understanding more about the design of the environments where wellbeing interventions are conducted. Further studies could apply our methodology to other environments to determine their capacity to enhance the benefits of MBSR. For example, it would be interesting to compare forest environments with blue environments as both have been found to offer particular benefits for mental health and wellbeing (e.g. Lee *et al.*, 2011).

Despite its limitations, this study has been one of the first attempts to examine the effectiveness of incorporating the beneficial effects of exposure to nature into a wellbeing intervention. We showed that 'MBSR in nature' as an effective therapeutic approach could support wellbeing and resilience, and improve mental health. Our study is focused on MBSR but more studies on the value of natural environments as settings for a wider range of health care programmes could encourage the NHS and other statutory providers to develop more effective interventions with local natural environments.

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List of tables

Table 1 Mean scores (and standard deviation) on questionnaires at four time points

Table 2 All main and interaction effects including the results of further analysis

List of figures

Figure 1. Research design

Figure 2. Three different experimental settings

Figure 3. CONSORT flow chart

Figure 4. Interaction graph for mindfulness; Error bars represent 95% confidence intervals.

Figure 5. Interaction graph for nature connectedness; Error bars represent 95% confidence intervals.

Figure 6. Interaction graph for positive affect; Error bars represent 95% confidence intervals.

Figure 7. Interaction graph for negative affect; Error bars represent 95% confidence intervals.

Figure 8. Interaction graph for rumination; Error bars represent 95% confidence intervals.

Figure 9. Interaction graph for the reflection; Error bars represent 95% confidence intervals.

Figure 10. Interaction graph for the depression; Error bars represent 95% confidence intervals.

Figure 11. Interaction graph for the anxiety; Error bars represent 95% confidence intervals.

Figure 12. Interaction graph for the stress; Error bars represent 95% confidence intervals.