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Beneficial effects on subjective mood and brain function of biophilic quality in university environments shown in virtual reality.

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ABSTRACT

Biophilic designs incorporate nature-based features into built environments. Raised theta activity is reported in biophilic environments. Virtual Reality allows greater control of experimental parameters than in-field studies. Participants provided subjective reports and underwent an electroencephalography assessment as they viewed interior spaces that varied (0 no features to 3 most features) in biophilic quality. Mood improved with biophilic quality. Theta power increased with biophilic quality for levels 1-3. Paradoxically, however, theta was also high in the condition devoid of biophilic features (Level 0). Findings suggest that the benefit of biophilic environments on mood is paralleled by alterations in theta.

1. INTRODUCTION

Urban living typically has an adverse impact on psychological wellbeing and health (Beyer et al., 2014; Engemann et al., 2019). The concept of biophilia (Fromm, 1964) proposes an innate need to engage with/exist alongside living-organisms and life-like processes that support wellbeing. Biophilic designs promote health by incorporating nature-based features into built environments (Gillis and Gatersleben 2015). The effect of biophilic built environments on brain function has been investigated using electroencephalography (EEG), which uses sensors placed on the scalp to measure postsynaptic changes in electrical potential produced during neuronal communication. Studies of biophilic building design show differences between urban and natural settings in theta activity (4-8Hz; Chen et al., 2020; Rounds et al., 2020; Jung et al., 2023). Chen et al. (2020), for example, show higher theta power recorded from participants seated in a garden than at traffic island. Change in theta was associated with increased vigour and reduced fatigue. Rounds et al. (2020) found theta increased during exposure to buildings/landmarks with biophilic features (ie., those that incorporated rotational twist designs and natural elements, such as trees and gardens). However, inconsistent findings exist (Grassini et al., 2019), and such in-field studies are difficult to experimentally control. Virtual Reality (VR) allows investigation of the effects of biophilic features during an immersive experience, whilst enabling control over other experimental parameters (Jung et al., 2023). The current study used VR to investigate self-reported mood and theta activity as a function of biophilic interior design features. Improvement in mood and increase in theta activity was expected as biophilic features increase.

2. METHODS

Participants (n=33; 18-90 years old) provided subjective reports and underwent EEG assessment (32 channels, Emotiv Flex, sampling rate = 2048 Hz internally downsampled to 128 Hz) as they viewed interior university spaces (classrooms, stairwells, corridors) that had either no biophilic qualities (level 0) or biophilic features (increasing intensity, levels 1 to 3; see Figure 1).

Stimuli were presented using an HTC Vive VR headset. At level one, the nature of the space was manipulated to allow refuge and prospect. Level two additionally included natural analogues. Level three added elements of nature in the space.

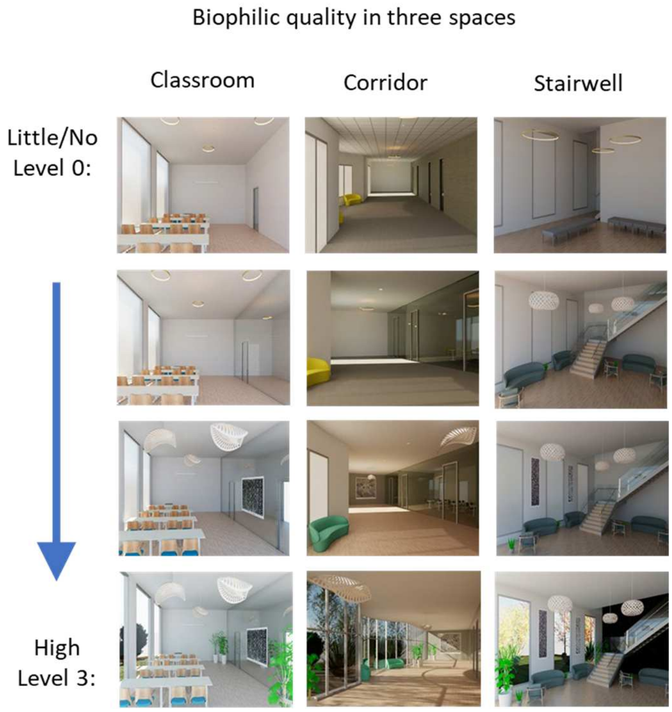

Figure 1. *Examples of stimuli. Level 0=no biophilic features; level 1= nature of the space altered; level 2= natural analogues added; level 3 = nature in the space added.*

Items from the Positive and Negative Affect Scale (PANAS; Watson and Clark, 1994) were used to measure subjective responses, based on four theories for biophilic benefit. Thus, these subjective responses included a positive- and a reversed-scored item to measure: i) Recovery from stress (*De-stress*; relaxed vs irritable); ii) *Restoration* of attentional resources (attentive vs fatigued); and iii) Provision of *Refuge* and prospect (self-assured vs frightened); and/or iv) fostering *Inspiration* and creativity (inspired vs downhearted). Signal processing was performed using EEGLAB (Delorme and Makeig, 2004). Data were re-referenced to the average and filtered using a 0.1Hz high-pass filter and a 60Hz low-pass filter. 30s epochs were created and independent components analysis was used to reduce ocular, cardiac and muscular artifacts. Epochs with residual artifacts were removed. Fast-Fourier transform was used to extract theta (4-8 Hz) power. Analysis of Variance was used to test for differences in PANAS scores and theta power as a function of biophilic *Level* (0, 1, 2, 3). Theta analysis was conducted at midline sites with an additional within groups variable, *Region* (frontal Fz, central Cz, parietal Pz); and at Lateral sites with *Region* (anterior frontal AF3/4, frontal F3/4, frontocentral FC3/4, central C3/4, centroparietal CP3/4, parietal P3/4) and *Hemisphere* (left, right) as additional within groups variables.

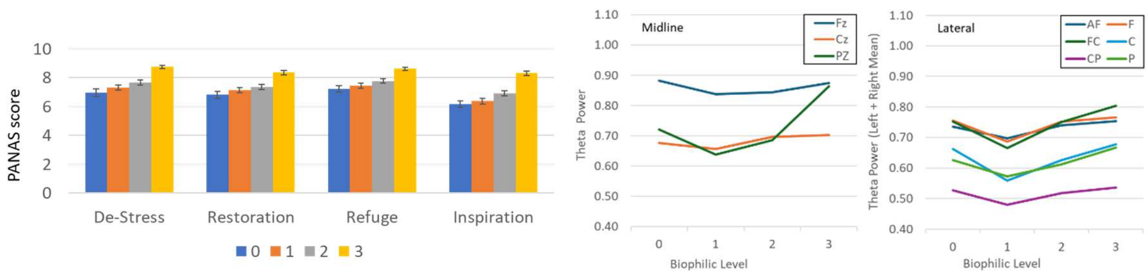

Figure 2. *Means for subjective response (left panel, error bars show standard error of means) and theta power (uV^2/Hz, right panels) as a function of 0-3 biophilic features. Lateral theta power was recorded over anterior frontal (AF), frontal (F), frontocentral (FC), central (C), centroparietal (CP) and parietal (P) regions.*

3. RESULTS

Figure 2 shows mean PANAS reports (left panel) and theta power (right panels) as a function of *Level*. For PANAS, there was a significant effect of *Level* (multivariate $F=8.41^{(12, 21)}$, $p<.001$, $p\eta^2=.83$, univariate $p<.001$ for each measurement). Effect sizes ranged from Restore ($p\eta^2=.46$) to Inspire ($p\eta^2=.60$). Theta at midline electrodes

(Fz, Cz, Pz) showed a significant effect of *Level* [$F=3.60^{(2.59, 83.00)}$, $p=.022$, $p\eta^2=.10$] and a significant *Level* x *Region* interaction [$F=2.99^{(2.58, 82.63)}$, $p=.043$, $p\eta^2=.09$], which was due to a significant effect of *Level* at Pz [$F=5.93^{(1.78, 57.00)}$, $p=.006$, $p\eta^2=.16$]. There was also a significant effect of *Level* at lateral sites [$F=5.47^{(2.44, 77.92)}$, $p=.004$, $p\eta^2=.15$]. No significant interactions were seen between *Level* and *age*, when included as a continuous covariate.

4. CONCLUSION

The current study used virtual reality to investigate the effect of biophilic features on mood and EEG theta power. Virtual reality provides advantages for a more robust experimental design, due to allowing deeper experiential immersion than images presented through 2D monitors and greater control over experimental parameters than real life. Self-report responses were based on four theories for biophilic benefit: Stress reduction, Attention Restoration, Refuge provision, and fostering Inspiration. In line with hypotheses, findings suggest an increase in biophilic features is associated with improvement in all subjective measures, with the greatest effect size for Inspiration. Moreover, the benefit of biophilic environments on mood is paralleled by alterations in brain function, independent of age. In line with previous work (Chen et al., 2020; Rounds et al., 2020; Jung et al., 2023), increasing biophilic features were associated with increases in posterior and lateral theta power. However, paradoxically spaces devoid of biophilic features showed higher theta than those with few biophilic features. This might reflect involvement of theta subtypes, that are differentially involved in positive and negative affect. Posterior midline theta has been associated with dopaminergic reward pathways and extraversion, whilst anterior theta has been associated with neuroticism (Chavanon et al., 2011). Theta subtypes may be related to specific elements in the biophilic designs. Future research on more design variations and incorporating other complementary psychophysiological measures (e.g., heart rate, skin conductance) would further support these ideas. Furthermore, confounding variables, not directly associated with biophilic features (e.g., stimulus complexity), might also have affected findings and should be investigated in future studies. Nevertheless, these novel findings contribute to an emerging body of evidence supporting the psychological benefit of biophilic built environments and underpinning brain mechanisms. Such evidence is important for policy decisions around the protection of green spaces, particularly in expanding urban areas, and for the design of built environments for work, education and healthcare facilities.

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