Research Article

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No Effect of Forest Representations on State Anxiety, Actual and Perceived Noise

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Abstract: Previous research indicates that nature and nature representations might have positive effects and noise negative effects on various facets of life, such as performance, perceived life quality, and physical and mental health. In this intervention, we observed whether posters showing a representation of nature (forests) can be used to reduce actual noise, perceived noise, and state anxiety in university library users. Measurements were taken twice daily for a 5-day period pre-intervention (before posters were installed) and again during the intervention, when posters were installed. No significant differences were found for perceived or actual noise levels or for self-report state anxiety levels between pre-intervention and intervention phase. Correlations between actual and perceived noise, and actual noise and state anxiety, were small in their magnitude and non-significant, with the exception of state anxiety and perceived noise during the intervention phase, suggesting a weak positive relationship. Finally, in hierarchical linear regression models, actual and perceived (overall and talking) noise and intervention phase were non-significant predictors of state anxiety. Small effect sizes of nature representations on state anxiety, as well as actual and perceived noise, suggest posters of forests to not be an effective intervention for anxiety and actual and perceived noise reduction in a university library.

Keywords: nature representations, posters, library, noise, state anxiety

1 Introduction

As we are daily moving within built environments, their design influences various aspects of our lives by creating visual and auditory arenas. Noise, i.e. disturbing sound, is one aspect within these arenas, which can act as a stressor impacting health (e.g. in preschool employees, Sjödin et al., 2012), satisfaction and perceived life quality (Bergefurt et al., 2022; Leather et al., 2003), as well as work or school performance (Errett et al., 2006). A large body of research examined effects of noise on health with the congruent conclusion of possible different negative health outcomes such as increased blood pressure, pulse, and stress hormone levels – especially when exposed to higher noise levels over prolonged periods of time (e.g. Babisch, 2002; Evans et al., 2001; Schmidt et al., 2013; Van Kempen et al., 2002).

Related to this, the soundscape around us plays an important role for perceptual and attentional processes and can ultimately affect health outcomes (Kang & Schulte-Fortkamp, 2016). This can be expressed

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biophysically, as noise exposure can moderate adrenaline levels, blood pressure, impair endothelial function, and increase cardiovascular adverse events in healthy adults exposed to sleep-time noise (Schmidt et al., 2013, Van Kempen et al., 2002). Similarly, children living in noisier areas had elevated resting-pulse and cortisol levels, higher depressed quality of life scores, and increased stress levels and resting blood pressure compared to children living in quieter areas (Evans et al., 1998, 2001).

Such physiological effects also affect psychological functioning and health, such as attention capacity, performance, well-being, and life quality. For example, noise levels can moderate the impact of psychosocial stress in the workplace on job satisfaction and well-being (Bergefurt et al., 2022; Leather et al., 2003). Additionally, acute stress caused by noise impairs cognitive control which manifests in anterior cingulate cortex activity (Banis & Lorist, 2012). Accordingly, impaired or reduced performance may be another negative consequence of high-noise-level exposure, which seems to specifically apply when individuals' perception of elevated noise levels is negative (Errett et al., 2006). In educational contexts, Klatte and colleagues' (2013) literature review on noise effects on children's cognitive performance shows that indoor noise led to lower verbal performance, and chronic noise exposure to lower reading ability.

While the presented findings point to stress responses due to high noise levels usually from traffic and road works, other establishments in daily life might incorporate lower noise levels with a different soundscape in order to maintain high levels of productivity, such as office-like work environments. As the perception of noise is subjective and relative to expectations (Errett et al., 2006; Kang & Zhang, 2010), noise-induced effects can also be expected to occur in low-noise environments, yet rather expressed in the ability to focus. For example, office workers have reported problems focusing due to background noise (Banbury & Berry, 2005), and Swedish adults reported annoyance due to road traffic noise (Björk et al., 2006). Similarly, Norlander et al. (2005) showed that pupils focussed more effectively when noise levels were reduced, but their stress levels remained unchanged. Crucially, human interactions with noise seem to determine the perception of auditory comfort, not necessarily the actual noise levels (Kang & Zhang, 2010). This suggests that the quality (origin and kind) of the sound determines the extent to which it is perceived as noise, and how disturbing the noise is. Furthermore, the physical environment and activities executed within the environment might play an important role in assessing auditory comfort, which is in turn predictive of psychophysiological responses.

While the perception and hence attitudes of the physical surrounding differ across socio-economic groups (Purcell, 1987; Rodenas et al., 1975) and for individual differences such as personality traits (Abello & Bernáldez, 1986), particular environments containing nature features can provide attentional ease, as stated in the *Attention Restoration Theory* (Kaplan, 1995), leading to less disrupted perceptual processes (Steg et al., 2012), potentially reducing stress (Ulrich, 1991). For example, research showed that nature representation could improve participants' attention capacity (Raanaas et al., 2011), and that particularly aesthetic images (with nature features counted as aesthetic) can reduce physiological stress responses (Taylor, 2006). Considering auditory features of environments, nature sounds have been shown to improve health, increase positive affect, and reduce levels of stress and annoyance (Buxton et al., 2021). Additionally, auditive and visual features interact in the perception of an environment (Carles et al., 1999), showing the importance of their integrated assessment.

Several studies reported a positive effect of green spaces on health in populations living in urban areas (Brown et al., 2016; Cohen-Cline et al., 2015; Dimitrova & Dzhambov, 2017), which is, according to Dzhambov et al. (2018a), mediated, for instance, by social cohesion and physical activity. One important aspect to consider when looking at health benefits of green areas is noise, as green spaces seem to alter adverse health effects of noise (Dzhambov et al., 2018b; Gidlöf-Gunnarsson & Öhrström, 2007). In this context, Gidlöf-Gunnarsson and Öhrström (2007) observed citizens living in a high-noise urban area and demonstrated that access to green areas was important to improve wellbeing and reduce prevalence of stress-related mental illness. Furthermore, a relationship between the number of green spaces and the effect of road traffic noise on students' mental health has been suggested, where the negative effect of noise was higher in a neighbourhood with a lower density of trees (Dzhambov et al., 2018b).

Interactions between physical environmental features and psychosocial outcomes can also be expected at the workplace (Bergefurt et al., 2022; Leather et al., 2003). The relationships between nature and reduced stress might be transferable to nature representations, for example, installed at a workplace or library (Ulrich, 1991). Furthermore, negative affect, being closely related to current stress levels, can be reliably measured by assessing state anxiety (Spielberger et al., 1983), which will be the focus in this study. While there is no research observing the phenomenon, it can be hypothesised that nature elements or representations will influence state anxiety and noise in a university library setting. Moreover, nature representations might be a cost-efficient and sustainable way of improving mental health, and hence creating healthier learning and working environments. Although there is a growing body of research examining the effects of nature representations on stress levels and adverse effects of noise separately, no study has yet examined how state anxiety levels and perceived and actual noise levels are influenced by nature representations in one single study. Therefore, the research question in the current study is: "*Are nature representations an effective intervention to lower state anxiety, as well as lower actual and perceived noise*?"

1.1 The Current Study

As the previous paragraph outlines, not only the noise level but also the sound quality (white noise, talking noise [TN]) and noise perception matter in shaping an audio-visual perception of an environment. We hence differentiate between different types of noise and measure decibel (dB) levels in addition to the perception of noise. The main motivation of this study was then to integrate the accumulated knowledge from previous studies into a feasible intervention and test its effects in a real-world environment.

State anxiety, *perceived* noise, and *actual* noise were measured in a university library, testing the hypotheses that nature representations influence state anxiety (H_1) and that nature representations reduce perceived noise levels (H_2). Furthermore, while there is no previous research on visual intervention effects on auditory features in an environment, we hypothesised that introducing nature representations to the library would reduce actual noise levels (H_3). We further hypothesised that there is a positive relationship between actual and perceived noise (H_4) and that there is a positive relationship between (actual and perceived) noise and state anxiety (H_5).

2 Method

2.1 Participants

A total of 229 participants, university students, were recruited: 125 in the pre-intervention period and 104 in the intervention period. In accordance with the ethics review board decision, no information on participant age or gender were collected. Data were collected in accordance with institutional GDPR data storage rules: data were collected, digitalised, anonymised, and safely stored. Anonymisation refers here to destroying identifying information on participants, which is their email addresses, after data collection was completed. Email addresses were necessary in order to identify raffle winners and to control for duplicates and repeated participation in both phases. As an incentive, participants could enter a draw to win one of two £10 Amazon vouchers in each of the two intervention phases. A printed debrief was provided after each participation.

Informed consent: Participants were provided with information and gave their consent to participate.

Ethical approval: The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance with the tenets of the Helsinki Declaration, and has been approved by the Abertay University's Ethics Committee.

Figure 1: Stimuli images used for the posters.

2.2 Instruments and Measures

State anxiety was measured with Spielberger and colleagues' (1983) 20-item self-report State Anxiety Inventory (Cronbach's $\alpha = 0.92$; pre-intervention $\alpha = 0.93$,[1] intervention $\alpha = 0.91$ for original and imputed data sets) with questions such as "I feel calm" or "I am worried" resulting in a single total score with the items 1, 2, 5, 8, 10, 11, 15, 16, 19, and 20 being reversed. *Perceived noise levels* were measured on a scale from 1 to 6 ("not noisy at all" to "extremely noisy") based on the question "How noisy would you rate the sound emitted by different sources in the library?", particularly asking about overall noise and people talking. This differentiation was made as particularly TN was found to be disruptive during working in quiet environments (Banbury & Berry, 2005). We also asked participants whether there was any additional source of noise which was noted.

Finally, some explorative open-ended questions were used to control for the time spent in the library, the activity the library was used for, date of upcoming exams/deadlines, and in the intervention phase an additional question on whether the nature representations were noticed. *Actual noise levels* were measured in dB, collected with a Tacklife SLM01 Noise Decibel Meter (unprocessed/untransformed measures). Three different images of forests complying with the local fauna were selected (Figure 1) as the nature representation stimuli. Those should include most naturalness, to maximise the effect of perceived restoration (see Carrus et al., 2013).

2.3 Design

This *in vivo* or naturalistic intervention study had a between-group design containing a pre-intervention and an intervention phase testing different participants in each of the phases with $n = 14$ participating in both phases. Gender or age groups were not balanced between phases or controlled for, as this information was not sampled. In both phases, actual and perceived noise as well as state anxiety were recorded twice a day over a period of five consecutive weekdays (Monday to Friday). Participants' reported noise and state anxiety levels were measured to be compared between conditions and correlated, and (perceived and actual) noise used to predict state anxiety. Hypotheses, methods, and statistical analyses were pre-registered, followed by data collection and analysis. No a-priori power analyses were conducted as the goal was to include as many participants as possible during a pre-defined time of 5 working days for each phase. However, a sensitivity analysis conducted with the pwr package (Champely et al., 2017) in R (v3.6.3; R Core Team, 2020) suggests that with $\alpha = 0.05$, $\beta = 0.80$, and group sample sizes $n_1 = 125$ and $n_2 = 104$, a minimal effect of $d = 0.37$ can be observed when comparing groups. For two-sided correlations, assuming the same α- and β-level, the smallest observable correlation coefficient for both phases together is $r = 0.18$, $r = 0.25$ for phase 1 only, and $r = 0.27$ for phase 2 only. The minimally detectable effect size using linear regression is $f^2 = 0.035$, when calculating with the same α- and β-level, numerator = 1 and denominator = 227, but $f^2 = 0.064$ for phase 1 and $f^2 = 0.077$ for phase 2 only.

1 In two of the ten imputed datasets Cronbach's $\alpha = 0.92$ for phase 1, in eight of ten $\alpha = 0.92$.

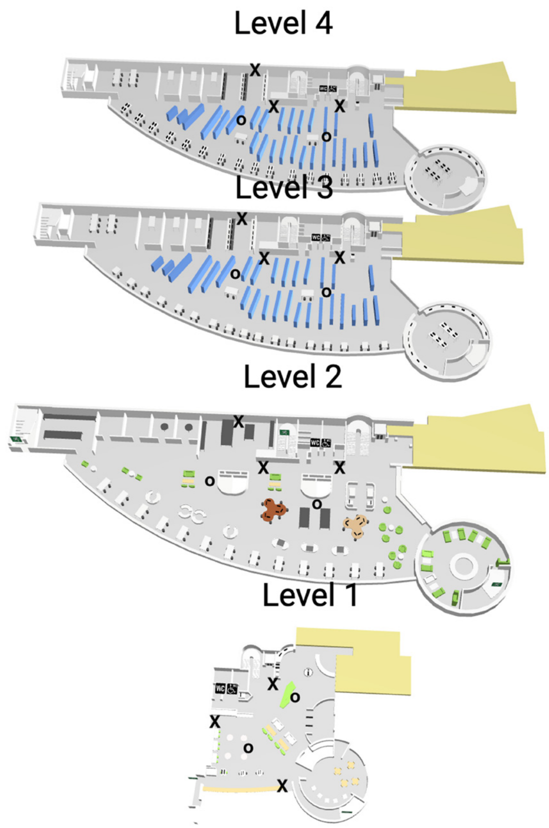

Figure 2: Locations of posters and measurements on the library's four levels. *Note*: *x* – poster location; *o* – actual noise in decibel (dB) measurement location.

2.4 Procedure

In the first intervention phase, actual noise levels were measured at two different central locations on each of the four library floors (Figure 2) at two points of time for five consecutive weekdays, at 12 pm and 2 pm. Afterwards, library visitors leaving the library were asked at a dedicated table at the library exit to complete the questionnaire on perceived noise and state anxiety over the course of 1 h at each session during the busiest hours (12–1 pm and 2–3 pm). The questionnaires were presented in printed form and completed with a pen or pencil.

For the second phase, three nature representations (Figure 1) were printed four times each on A1-sized posters (equalling 12 posters) and distributed in a random order on the four floors of the library. On each of the floors, three different posters were placed at the same locations on the main travelling routes on levels 2–4. Due to the differing architecture of level 1, the position of the posters differed slightly (Figure 2). Additionally, it is important to mention that the library has an absolute silence policy for the top level, and more social areas on the first two levels. The procedure in the intervention phase resembled the phase 1 procedure (noise measurements followed by questionnaires at the library exit). The study was conducted at the beginning of the academic semester and there was a 1-week break between pre-intervention and intervention phases. This choice was made to give a sufficient "cool off" time to avoid effects being introduced by the mere presence of researchers in the library during phase one (Hawthorne Effect, see Sedgwick & Greenwood, 2015). At the same time, it was important to represent a similar time of the semester in both pre-intervention and intervention phases of the study avoiding, for example, exams which would influence stress ratings.

Manipulation checks showed that of the total of $N = 104$ phase two participants, $N = 42$ noticed the posters (Figure 3). $N = 43$ indicated to not having noticed the posters, and $N = 19$ did not provide an answer. Half of the $N = 42$ who noticed the posters felt they made a positive impact on the environment.

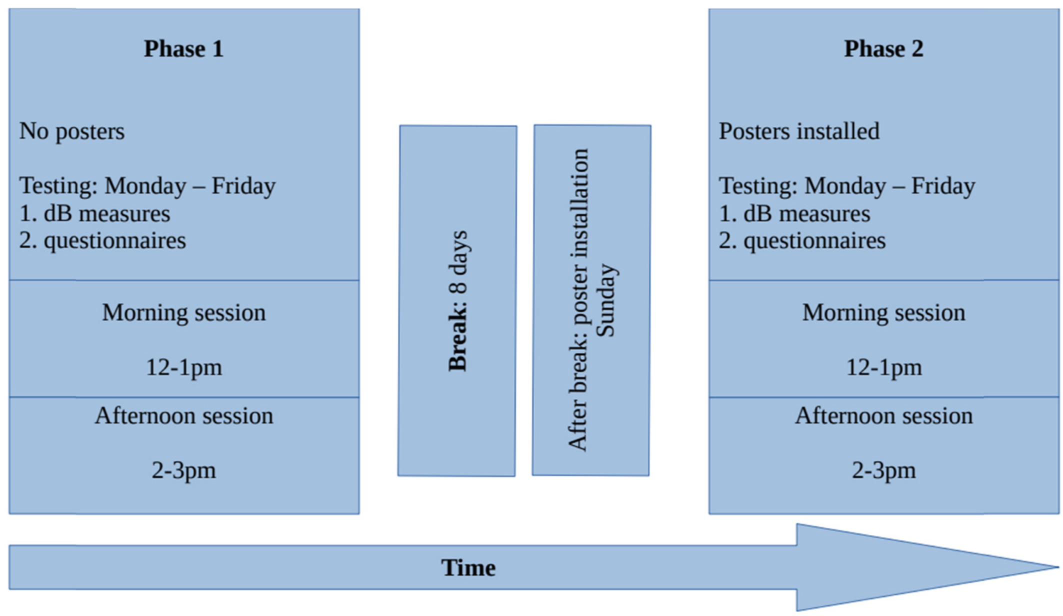

Figure 3: Study execution flow chart.

3 Results

Analyses were executed as stated in the preregistration on AsPredicted.org (https://aspredicted.org/i7wz4.pdf). As only 14 participants took part in both phases of the study, no repeated measures test could be conducted. Due to missing data[2] in the state anxiety inventory, 10 datasets were imputed using predictive mean matching multiple imputation with the MICE package (Zhang, 2016) i) 5 based on the 20 items only and ii) 5 based on the 20 items and their row-wise mean scores (irrespective of missingness at random), resulting in 11 datasets which were used in analyses involving state anxiety. Participants self-reported to spend on average 101.1 ± 73.3 min in the library across the two study phases with most of the participants engaging in quiet activities (studying and research), with some participants working on group projects and meeting friends.

Due to the non-normality of the self-report data, Mann–Whitney tests were used, revealing no differences pre- and during intervention in perceived overall noise levels ($r = 0.10$, $p = 0.117$), TN ($r = 0.09$, $p = 0.171$), or state anxiety ($0.06 > r > 0.04$, $0.658 > p > 0.308$), and actual noise levels ($r = 0.04$, $p = 0.642$), concluding in the rejection of H_1–H_3.

To make sure that variations in anxiety and noise level were not driven by time of measurement or floor/level of the library, first, Mann–Whitney U-tests were conducted showing no difference between perceived overall noise ($r = 0.04$, $p = 0.529$), TN ($r = 0.08$, $p = 0.246$), state anxiety ($0.02 > r > 0.01$, $0.992 > p > 0.831$) or actual noise for measurements taken between 12–1 pm and 2–3 pm ($p = 0.927$, $r = 0.01$). Second, a Welch's one-way test was conducted showing significant differences in actual noise levels between the four library levels [$H(3) = 103.11$, $p < 0.0001$, est $\omega^2 = 0.9979$], indicating that 99.79% of the total variance in actual noise levels was accounted for by the library level. Mann–Whitney post-hoc comparisons revealed significant differences in actual noise between all library levels, with only the difference between the first two floors being non-significant ($dB_{diff} = 2.6$, $p = 0.074$; Table 1).

2 Missingness at random of the state anxiety scale in phase 1: $N = 25$ datasets affected, phase 2: $N = 21$ datasets affected. Completely missing in phase 2: $N = 6$ (no mean score calculated based on these rows). There was no missingness among actual and perceived noise values. Missingness among the main variables of interest was exclusively observed in the state anxiety inventory, potentially due to the sensitive nature of the questions.

Table 1: Pairwise comparison of noise levels across floors

	Noise level in dB		Median differences		
	Mdn	**MAD**	**Level 1**	**Level 2**	**Level 3**
Level 1	56.2	4.08			
Level 2	53.6	6.00	2.6		
Level 3	46.6	5.49	9.6***	7.0***	
Level 4	42.7	6.52	13.5***	10.9***	3.9***

MAD – mean absolute deviation, ****p* < 0.001, *p*-values are corrected for false discovery rate (Benjamini & Hochberg, 1995).

Table 2: Correlations between state anxiety and perceived noise

	Correlations	r_s	***p*-value**
All data	SA&PON	$0.160 \geq r_s \geq 0.133$	$0.045 \geq p \geq 0.015$
	SA&TN	$0.162 \geq r_s \geq 0.142$	$0.032 \geq p \geq 0.014$
	AN&PON	0.142	0.032
	AN&TN	0.071	0.284
Phase 1 only	SA&PON	$0.126 \geq r_s \geq 0.126$	$0.207 \geq p \geq 0.162$
	SA&TN	$0.151 \geq r_s \geq 0.137$	$0.166 \geq p \geq 0.093$
	AN&PON	0.074	0.415
	AN&TN	0.009	0.919
Phase 2 only	SA&PON	$0.231 \geq r_s \geq 0.170$	$0.085 \geq p \geq 0.032$
	SA&TN	$0.189 \geq r_s \geq 0.137$	$0.166 \geq p > 0.055$
	AN&PON	0.227	0.415
	AN&TN	0.140	0.157

SA – state anxiety, PON – perceived overall noise, TN – talking noise, AN – actual noise.
Note: Multiple *r*- and *p*-values presented as a result of multiple imputation for the state anxiety inventory. Degrees of freedom were $df_{all} = 227$, and $df_{phase1} = 123$ and $df_{phase2} = 102$.

Looking at the relationships between actual and perceived noise, Spearman's correlations between state anxiety and perceived overall noise and between state anxiety and TN were all significant at $\alpha = 0.05$ across phases, but not for phases 1 and 2 separately (Table 2). Similarly, only across phases, there was a significant correlation between actual noise and perceived overall noise, yet not for actual noise and TN (Table 2). Relationships between state anxiety and actual noise were not significant for all data ($0.642 > p > 0.456$), pre-intervention ($0.860 > p > 0.758$), and during the intervention ($0.717 > p > 0.449$) (Table 2).

Furthermore, hierarchical linear regressions were run with i) a null-model predicting state anxiety from phase [$F(1, 221) = 0.38$, $p = 0.537$, $R^2_{adj} = 0.003$, $f^2 = 0.002$], to which we step-wise added ii) perceived overall noise [$F(2, 220) = 1.70$, $p = 0.185$, $R^2_{adj} = 0.006$, $f^2 = 0.015$], iii) TN [$F(3, 219) = 1.25$, $p = 0.293$, $R^2_{adj} = 0.003$, $f^2 = 0.017$], and iv) actual noise [$F(4, 218) = 1.07$, $p = 0.362$, $R^2_{adj} \sim 0$, $f^2 = 0.018$], revealing no significant predictors of state anxiety, yet in the second model containing phase and overall perceived noise perception as predictors of state anxiety, perceived overall noise was the overall strongest, yet non-significant predictor $b = 0.05$, $p = 0.084$. Hence, when comparing models using an analysis of variance, adding overall noise perception to the null-model improved the model, yet below the threshold of significance, [$F(1, 221) = 3.00$, $p = 0.085$]. However, adding TN [$F(1, 220) = 0.35$, $p = 0.557$] and actual noise levels [$F(1, 219) = 0.09$, $p = 0.767$] did not improve the model. As a non-preregistered explorative quality-control step, we first applied generalised additive models as an alternative to account for non-linear relationships between the variables of interest. The results were close to those from linear models: none of the added predictors were significant (*ps* > 0.218), likelihood ratio tests indicated no significant differences between baseline model and models with added independent variables (*ps* > 0.167), and variance explained was low, with the highest value for the model explaining state anxiety from both talking and overall noise ($R^2_{\text{raw}} < 0.016$). As a final quality-control step, we reanalysed the group of library visitors who indicated having noticed the posters yielding non-significant models explaining state anxiety (*ps* > 0.224, $R^2_{\text{adj}} <$ 0.006), with none of the predictors significantly contributing to the model (*ps* > 0.224). Considering the small contributions of actual and perceived noise to the models and low model fit, H_5 can be rejected.

4 Discussion

No significant differences of perceived and actual noise levels or state anxiety were found between the pre-intervention phase and the intervention phase. Small correlations were detected between state anxiety and perceived (talking and overall) noise, only strong enough when examining intervention phase data independently and not the entire sample, given the limited sample. All other correlations between state anxiety, perceived noise, and actual noise were non-significant. Finally, linear models with actual and perceived noise levels and phase of study could only explain a small portion of the overall variance of state anxiety. Furthermore, adding perceived and actual noise levels step-wise to the model did not significantly increase model fit, with the exception of overall perceived noise approaching significance, giving an indication of a potential effect.

Other studies have consistently reported positive effects of nature or nature representations, for example, on health (Brown et al., 2016; Cohen-Cline et al., 2015; Dimitrova & Dzhambov, 2017) or to avoid negative health consequences of noise (Dzhambov et al., 2018b; Gidlöf-Gunnarsson & Öhrström, 2007). However, the current results suggest that these positive effects of nature representations do not apply to state anxiety, noise perception, or actual noise. Although there might be variations among different populations and students of different programmes and year of study, a recent study (Korbmacher & Wright, 2020) did not find differences in perceived stress levels across the dissertation year, which is strongly correlated with state anxiety (e.g. Petrac et al., 2009). This advises that the presented evidence for the null hypothesis (no effect of nature representations on state anxiety) is not due to fluctuations of anxiety levels.

Numerous arguments can be made to explain why placing nature representations in the library did not affect state anxiety and noise levels. *First*, noise levels might generally have been too low to influence state anxiety ratings, and background noise might become a habituated stimulus after a short time (Banbury & Berry, 1997). The noise levels in the library at around 50 dB across the different library levels/floors might have been so low that they were not influencing library visitors' ability to focus and state emotions (Mehta et al., 2012). Moreover, students might have listened to music via headphones, leaving them unaffected by environmental noise and positively influencing affect and productivity (Lesiuk, 2005). In these cases, library visitors might have been unaffected by the environment. Additionally, posters might only induce small changes in noise emission, perception, or anxiety levels requiring a larger sample to reliably detect such small effects. As presented in Table 1, noise levels differed significantly on the different library levels. Students might hence have chosen a place to sit with an acceptable noise level to suit the task they were doing. At the same time and without counting the exact number of visitors at each level of the library, the two lower levels (1 and 2) were most likely more populated as services such as a coffee shop, vending machines, and the student enquiry zone are located on level 1. Additionally, state anxiety and perceived overall noise as well as actual and perceived overall noise levels were only correlated in the intervention phase, which might be due to an awareness-creating effect of the posters or biased participants, for instance, through the "good subject effect" (see Nichols & Maner, 2008), or bias introduced on the way out of the library. For example, state anxiety could change on the way out of the library, convoluting the relationship between forest images. We recommend applying the study design to noisier and more busy places such as train station waiting areas or cafeterias and provide questionnaires at the place of interest via QR codes (rather than at the exit of the building). This would not only diffuse experimenter effects, but also make it possible to observe whether nature representations are more effective in high-noise environments.

Second, there are differences between nature representations and nature. For example, Dzhambov et al. (2018a) describes a variety of mediators in the relationship between green spaces and health, such as social cohesion and physical activity. These moderators are not given in the same way when just providing posters as nature representations instead of usable spaces. Moreover, according to Kaplan's (1995) *Attention Restoration*

Theory, green spaces have a greater restorative potential when individuals are placed in them compared to being placed in built environments including few nature representations. Kaplan describes that more features need to be cognitively processed in built environments. However, differences in mediators for health outcomes between nature/green spaces and nature representations still require further research. Related to this, implementing plants in library contexts could be a stronger intervention stimulus used in future studies. Additionally, further laboratory-based experiments would be helpful to disentangle the impact on state anxiety and noise different nature representations (such as potted plants compared to posters) might have.

Third, the posters' characteristics might contribute to not detecting true effects by influencing or even disallowing the posters' perception. For example, the posters' positioning, size, colours, and contents influence whether posters were perceived and processed. Moreover, drawing attention to the posters might be required to cause effects, which is otherwise focused on the built environment which does not have the same restoring and "calming" effects as nature or nature representations (Kaplan, 1995; Ulrich, 1991). A1 posters might not be a cue strong enough to influence state anxiety and noise levels in a library as they perhaps did not catch participants' attention sufficiently. Although still in need of refinement, different measures of health outcomes by the amount of green space indicate that more green spaces lead to better health in the area (Rugel et al., 2017). The ratio of posters/m^2 seems to be influential and might have been underestimated. The posters were placed at the main walking routes in the library. However, a more thorough analysis of the library users' walking patterns (e.g. as in Vich et al., 2019) and gaze directions (e.g. using mobile eye-tracking systems, see Foulsham & Kingstone, 2011) could have provided clearer directions of where to place the posters. Based on these outcomes, the poster size, colours, contents, and position could then be altered in order to be (more) noticeable. How to optimise these parameters to maximise attention to posters or other nature representation requires further experimental investigation, for example by presenting participants with videos or images of built environments with different nature representations implemented. As a follow-up of such video or image sequence, participants could be asked about quantity and quality of the nature representations.

Fourth, we measured state anxiety, which is a construct related to stress (Spielberger et al., 1983). However, other instruments might have been more suitable to measure noise-induced discomfort or stress. In the light of the Attention Restauration Theory, measuring attentional features might have been useful, and, in general, scales which directly measure perceived stress such as the Perceived Stress Scale (Cohen et al., 1983), or those which measure a broader emotional state space such as the Positive and Negative Affect Scale (Watson et al., 1988).

Most correlations between perceived and actual noise were small and non-significant, suggesting a replication on a much larger sample to examine such small effects reliably. However, nature representations themselves or nature representations embedded in the library/study context including a researcher asking for participation at the front door of the library might support an increased awareness of noise (e.g. Nichols & Maner, 2008). Although only 14 participants took part in both pre-intervention and intervention sessions, it might be that participation was primed for some due to the presence of the researcher in the library during the pre-intervention phase, leading to a generally greater stimuli-awareness. While this might be the case, only pre-post intervention data can be used when the goal is to infer causality, potentially in future studies with controlling for additional confounds targeting bias induced by researcher presence. A remaining, unavoidable sampling bias is that library visitors with higher state anxiety might have been less willing to participate in the study. Moreover, although different from zero, the significant correlation coefficients for actual and perceived

Table 3: Perceived noise, actual noise, and state anxiety scores in the original data by phase

	Pre-intervention			Intervention		
	Mdn	**M**	**SD**	**Mdn**	**M**	**SD**
Overall noise	3.00	2.89	1.06	3.00	3.14	1.09
Noise from people talking	3.00	3.26	1.34	3.00	3.46	1.12
Actual noise (in dB)	48.95	49.04	8.04	50.15	49.41	7.07
State anxiety	1.85	1.89	0.53	1.75	1.84	0.52

noise and also actual noise and state anxiety were only small, and below or close to the minimum detectable effect sizes estimated by the sensitivity analyses, highlighting the possibility of them being false positives.

Furthermore, in the regression models, actual and perceived noise were poor predictors of state anxiety. This finding counteracts previous research showing that noise increases state anxiety levels (Standing et al., 1990; Standing & Stace, 1980). However, participants in these studies were exposed to white noise louder than 61 dB, whereas noise levels in the current study were on average approximately 50 dB, consisting of background noise of different frequencies (in both phases; Table 3). Hence, the noise was not only differing in volume but also frequency range. Although no clear threshold could be identified at which physiological, for example cardiovascular, adverse effects of noise appear, there are some studies showing adverse health effects caused by noise levels around 50 dB, with a higher number of studies making use of paradigms using noise levels higher than 50 dB (van Kempen et al., 2002). Thus, effects of noise might not be independent of noise perception. For example, having a higher noise sensitivity increases state anxiety levels (Park et al., 2017) and decreases attention (Tristan-Hernández et al., 2017), productivity (Meegahapola & Prabodanie, 2018), as well as performance (Errett et al., 2006) when exposed to noise. This is reflected by our data indicating overall noise perception as a predictor of state anxiety. In turn, noise perception seems to be influenced by a range of variables such as current mood (Västfjäll, 2002). Hence, future studies could include further variables in addition to actual and perceived noise levels in a model used to predict state anxiety as a function of noise, such as mood and noise-sensitivity measures, and, in line with Attention Restoration Theory, measure attention. Finally, publication bias in the literature on nature representations' effects on state anxiety or on associations between actual and perceived noise cannot be excluded, which urges to also re-assess the literature meta-analytically.

5 Conclusion

Against the trend of studies showing positive effects of nature representations on mental health, we could not find any differences in state anxiety after implementing nature posters as an intervention in a university library. We tested a new approach of using nature representations to reduce actual and perceived noise levels, with the data not supporting the approach to cause changes. Although it could not be demonstrated in this study that an intervention with posters as the choice of nature representations impacted noise levels or state anxiety, other methodologies might lead to such effects, for example, when conducting studies with similar or other nature representations (e.g. plants) and settings (e.g. coffee shops) in controlled environments. Assuming low effect sizes for such interventions, their practical significance might however be low in library settings, yet potentially stronger in other settings such as high-noise environments. A long list of factors such as the loudness, volume, frequency spectrum, the nature representations and noise perception, awareness, features and location the nature representations are embedded in, or sample characteristics such as age, gender, or profession might be influential variables which require further investigation. Hence, further research is needed to widen the understanding of the impact of nature representations on state anxiety as well as perceived and actual noise in different context and populations, and their usability in practical settings.

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