The Journal of Health Design

STUDY PROTOCOL

Psychological and physiological effects of visual stimulation with real plants and artificial natural structures: A study protocol for a randomised controlled trial

Luca Bettinger[1] and Roxana Schweighart[2]

1. University of Applied Sciences Würzburg-Schweinfurt, Würzburg, Germany
2. University Vechta, Vechta, Germany

To Cite: Bettinger L, Schweighart R. Psychological and physiological effects of visual stimulation with real plants and artificial natural structures: A study protocol for a randomised controlled trial. JHD. 2022;7(3):513–522. https://doi.org/10.21853/JHD.2022.181

Corresponding Author:
Luca Bettinger
University of Applied Sciences Würzburg-Schweinfurt, Würzburg, Germany
luca.bettinger@student.fhws.de

SUMMARY
The positive effects of the natural environment on human health are well studied. However, it is not always possible to use real natural environments or plants in healthcare settings. We would like to develop a low-cost, effective, and aesthetic alternative. For this purpose, we designed artificial natural structures based on fractal geometry. Within the framework of a randomised controlled trial, we would like to investigate their effect on different variables (stress, emotions, pulse, and blood pressure) in humans. An indoor plant will serve as a comparative condition. In addition, we will conduct a control condition without stimulus.

Key Words
Biophilia; houseplants; well-being; design; aesthetics

ABSTRACT

Background
The link between natural environments and positive effects on humans is well established. Spending time in nature or naturally designed spaces is associated with positive physiological and psychological effects. The study is based on the following research question: Do artificial natural structures have similar positive effects on humans as indoor plants?

Aims
In this intervention study, we would like to investigate the potential of artificial natural structures, which are inspired by fractal geometry.

Method
For this purpose, we will conduct a three-arm randomised controlled trial to test the following hypothesis: Viewing artificial natural structures has positive effects on participants, comparable to the effect of indoor plants. We expect the natural structures to lower stress levels, blood pressure, and pulse, and improve emotional aspects such as well-being and relaxation. We expect the effect to be similar to viewing an indoor plant. For this purpose, we will carry out two interventions (visual stimulation by an ivy plant and by the artificial natural structures) and a

control situation.

Conclusion

We assume that in the group exposed to the artificial natural structures, positive effects can be observed for several variables. We would like to use the findings to develop an aesthetic, health-promoting, and cost-effective biophilic design for flexible use in rooms and buildings.

BACKGROUND

Since 2007, more people live in urban areas than in rural areas. Currently, more than 4 billion people are living in cities, and the trend is rising. This development is particularly strong in high-income countries. In Western Europe, America, Australia, Japan, and the Middle East, more than 80 per cent of the population lives in urban areas.[1] Although urbanisation sometimes brings positive changes to people's health, such as increased access to social or health services, people living in cities may also face increased health risks.[2] For example, urbanisation may be associated with an increase in lifestyle risk factors such as physical inactivity, low fruit and vegetable consumption, and high body mass index, which may ultimately lead to an increased risk of cardiometabolic disease.[3] Increasing urbanisation may also have negative consequences on mental health. A literature review of 113 included studies suggests an association between living in an urban area and lower mental health due to social, economic, and environmental factors prevalent in cities. These include social inequalities, social insecurity, pollution, and lack of contact with nature.[4] Some mental illnesses, such as depression[5], eating disorders[6], schizophrenia[7], and anxiety disorders[8], are more common in urban areas than in rural areas.

Conversely, a natural environment has positive effects on people. Numerous studies support this assumption, as the following examples illustrate. One review paper, for instance, examined the effects of different forms of nature therapy, including forest therapy/forest bathing, urban green space therapy, plant therapy, and wood material therapy.[9] The included studies were examined in terms of physiological indicators such as brain activity, autonomic nervous system activity, endocrine activity, and immune activity. The researchers found positive effects of the nature therapy forms and attribute great importance to this form of health promotion in the future.[9]

Mental health also appears to benefit from nature and nature-based spaces. Mindfulness-based stress reduction (MBSR) training conducted in a natural outdoor setting leads to better mental health and well-being than the same training conducted indoors.[10] Viewing indoor plants can also have positive effects, such as higher scores for "comfort", "naturalness", "relaxation", increased positive mood[11], or decreased feelings of stress.[12] However, not only viewing real plants can result in positive reactions. Viewing artificial plants[11] or images depicting natural sceneries[12-14] is associated with greater well-being.[11] When viewing landscape images, participants sometimes felt more natural, relaxed, and at ease and had lower anxiety scores than after viewing images depicting urban scenes.[13] The colour green is often associated with positive emotions such as relaxation and comfort.[15] Thus, the colour design of the environment alone can have positive effects on people. However, a new study shows that the positive effect is due to an image of plants rather than to the green colour. The combination of green colour and an image of plants seems to be particularly health-promoting.[16] Healthcare providers can take advantage of these effects as part of health promotion efforts. Patients placed in a room with plants after surgery had lower systolic blood pressure, less pain, and less anxiety and fatigue than patients in the control group.[17] The positive effects associated with exposure to nature and images of nature may be explained in part by the perceived attractiveness of the environment, plants, and images.[12,18]

In many healthcare settings, the use of real plants is either impractical or sometimes even prohibited, including in hospitals and clinics due to hygiene standards. For example, fungal spores associated with mycoses in patients may be present in plant soil.[19] Also, indoor plants cannot always be used safely in nursing homes because people with dementia sometimes tend to eat the plants or soil.[20] For these environments, effective alternatives for real plants may be important.

AIM OF THE STUDY

The study aims to investigate whether artificial natural structures—ie, artificially imitated nature—have the same or a similar effect on participants as the sight of real natural things such as an indoor plant. Within the framework of the planned study, we will investigate the effect on the participants' stress perception, mood, blood pressure, and pulse. In addition, we aim to find out which installation (indoor plant or artificial natural structures) the participants find more visually appealing and which room atmosphere they find more pleasant. Especially in environments where real indoor plants cannot be used—eg, operating theatres, hospitals, etc.—artificial natural structures could be a good alternative due to their flexible and cost-effective applicability. Due to the aesthetics of the artificial natural structures, they could be a visually appealing alternative for images of plants or nature scenes. The aim of this project is to develop an aesthetic, health-promoting, and cost-effective biophilic design for flexible use in rooms and buildings.

HYPOTHESES

We have three hypotheses:

1. Viewing artificial natural structures has positive effects (less stress perception, better mood, lower blood pressure, lower pulse) on the participants, comparable to the effect of an indoor plant.
2. The participants perceive the atmosphere in the room with the artificial natural structures to be just as pleasant as the atmosphere in the room with the indoor plant.
3. The participants perceive the artificial natural structures to be just as visually appealing as the indoor plants.

METHOD/STUDY DESIGN

The first author developed the nature-imitating installation (artificial natural structures) as part of his master's degree in information design at the University of Applied Sciences Würzburg-Schweinfurt. His goal was to answer the design research question of whether nature can also be artificially reproduced using purely technical means. For this purpose, he developed artificial natural structures based on principles of nature. Fractal geometry served as a source of inspiration, as it occurs frequently in nature. It describes the hierarchical repetition of the same shape on several scaling levels.[21] A concise example of this is the fern, which consists of leaves that, in turn, look like small ferns themselves.

The structure examined here is based on a purely technical-looking basic form that the authors designed digitally. In the second scaling stage, we arranged a large number of the basic elements in an enlarged shape that again conforms to the basic shape. The result is an organic structure that can now be combined with identical elements to form a larger structure.

After creating the basic shape, as well as the scaling levels, we cut the structure out of dark green polyester felt sheets with a laser. The basic characteristic of polyester underlines the artificial character of the structures. In addition, felt is suitable because of its texture, as its fibres are reminiscent of moss. We illustrate the different scaling levels of the structure (Figures 1–3).

Figure 1: Basic element, first scaling level

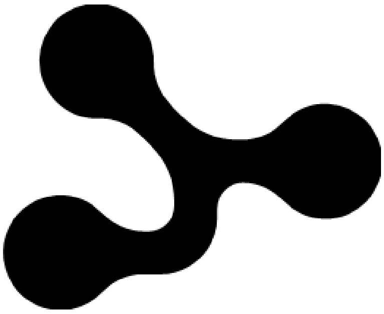


Figure 2: Second scaling level

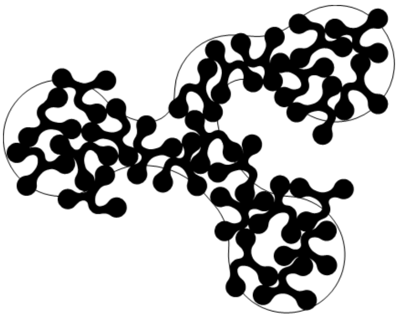
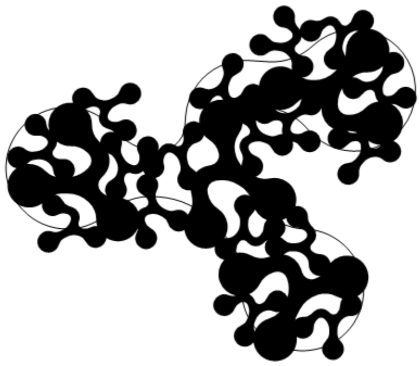


Figure 3: Third scaling level



Participants

We will enrol participants in the study if they meet the following inclusion criteria: 1) they are older than 18 years of age; and 2) they can voluntarily consent to the study.

Participants will be excluded if any of the following exclusion criteria are met: 1) they already know about the project; 2) they have severe visual impairments; and 3) they have mental illness.

Recruitment

Potential participants who meet the inclusion criteria will be invited to take part in the study. Recruitment will occur via social media networks such as local Facebook groups, but also by using information signs in the area near the university. We will invite participants to take part in the study without pre-registration. We will conduct the study over several days, so we hope to reach a sufficiently large number of participants. Before data collection, we will explain in detail to the participants the study's aim, procedure, and data protection. Subsequently, the subjects will give their written consent. Upon consent, we will check whether the participants meet the inclusion criteria. If the inclusion and exclusion criteria are checked positively, the interested participants will take part in the study. Participants can withdraw from the study at any time during the data collection until the completion of the data analysis. For this purpose, the participants' contact details are assigned to an identification number using a list. This list will be destroyed after the completion of the data analysis. Withdrawal from participation is no longer possible thereafter. We will inform the participants of this in advance.

Randomisation process

We will assign participants to one of the three conditions using computer-generated randomisation software.

Sample size

We calculated the sample size a priori with GPower.[22] Assuming an effect size f of 0.20, an alpha level of 0.05, a power of 80 per cent, three groups, and two measurement time points, this results in a required sample of 66 subjects. Since the data at the first and second measurement time points are collected in close succession, we assume that there will be few to no dropouts, so this does not need to be considered in the sampling.

Procedure

In this study, we will investigate two interventions and one control situation. In room 1, participants will see the artificial natural structures placed on a wall. In an identical room, an indoor plant (ivy, Latin name: Epipremnum aureum) will be placed on the same wall. Both installations will take up the same area on the wall. In a third room, which will also be identical in construction, the wall will remain empty. This experimental room will serve as a control room. In all three rooms, an identical chair will be placed at the same distance from the centre of the wall (approximately 2 m) on which the participants will be seated. The rooms will be painted white and the windows will be darkened during the study to exclude effects due to different lighting conditions. The temperature will be kept constant in all three rooms and we will reduce background noise near the experimental rooms as much as possible. We present the wall installations of room 1 and room 2 (Figures 4 and 5).

Figure 4: Artificial natural structures on the wall

Figure 5: Indoor plant on the wall

We will conduct the study on two consecutive days, during which the study setup will remain in place. When the study participants arrive, they will be asked to take a seat in a waiting room. The study participants will then receive information about participation in the study and an informed consent form. After returning the signed consent form, we will collect baseline data, which will take 5 to 10 minutes. First, we will measure the participants' pulse and blood pressure, then we will ask them to fill out a questionnaire. Subsequently, randomisation will be performed with the assistance of computer software. After the assignment to the interventions, there is no blinding.

After the assignment, we will escort participants to their respective rooms. We will ask them to sit in the chair and stay there for the duration of the study, to put their mobile phone on airplane mode, and not to use it. In the two experimental rooms, the visual stimuli will be covered at the beginning (there will be whiteboards in front of the walls). Then the intervention will take place by removing the boards and leaving the participants in the assigned room for three minutes. We assume that after this time the expected effects will be measurable since in the study of Ochiai et al.[23] effects were already detectable after one minute following visual stimulation by a bonsai plant. After the three-minute intervention phase, the stimuli will be covered again and we will collect data at time point T2. Again, we expect the data collection to take 5 to 10 minutes. We will measure pulse and blood pressure a second time, and then the participants will fill out the second questionnaire. We present the participants' path from recruitment to completion (Figure 6).

Measuring the Results

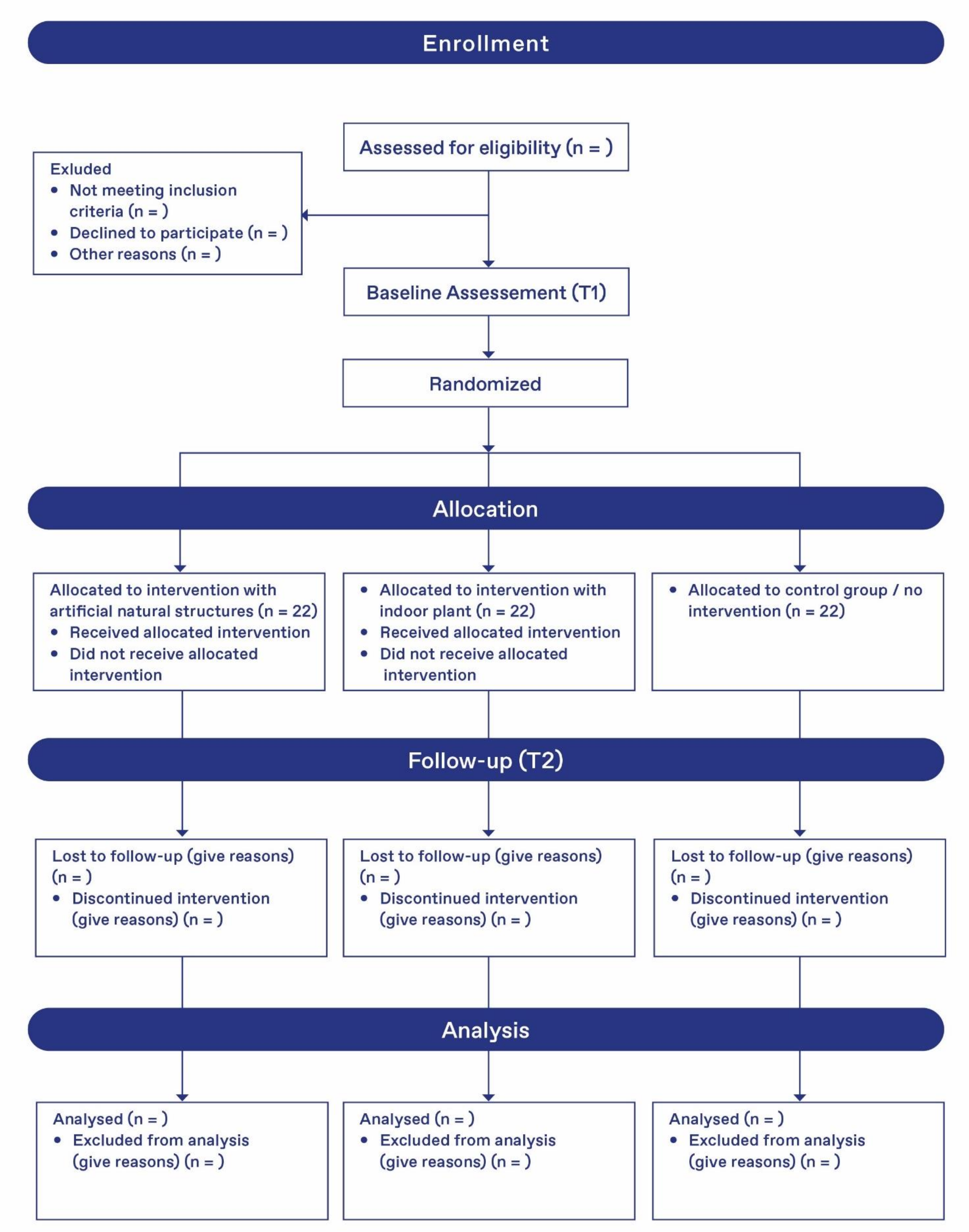
We will collect sociodemographic information using a questionnaire that assesses gender, age, high school graduation, and marital status.

We will collect stress as the primary measure. For this purpose, we will use the still relatively unknown 10-item Short Regensburg Stress Scale (StReSS-10), which contains 10 items from the commonly used Perceived Stress Questionaire (PSQ).[24] We chose this instrument because it is based on the PSQ, but the instructions ask about current feelings of stress and do not collect data concerning the last four weeks as in the PSQ. For the German version of the 20-item PSQ, good values for the internal consistency of the scales were found (Cronbach's alpha between = .87 and = .79). Validation of the German version of the PSQ also provides evidence for construct validity as well as external validity.[25] Secondary measures include physiological values such as pulse and blood pressure. For this purpose, we will use a device that measures pulse and blood pressure at the wrist (Curamed BDU 751). Moreover, secondary measures include current mood, four current emotional states (relaxation, anxiety, contentment, and well-being), the atmosphere of the room, and the aesthetics of the installation. We will use the Current Mood Scale (ASTS)[26], adapted from the Profile of Mood (POMS)[27], to assess mood, using 19 items and 5 subscales (sadness, hopelessness, fatigue, anger, and positive mood).

We will use the semantic differential method (SDM) to assess relaxation, anxiety, satisfaction, and well-being. We will assess the rooom's atmosphere using four self-developed items to evaluate whether the artificial natural structures, as well as the plants, create a more pleasant atmosphere in the rooms than the white wall without installation. We will assess the aesthetics of the installations using a 10-point scale from very aesthetic to not at all aesthetic (SDM).

We will only collect sociodemographic information as part of the baseline data (T1). At baseline (T1) and after the intervention (T2), we will obtain stress and mood measures, SDM on relaxation, anxiety, satisfaction, and well-being, and physiological measures. In contrast, we will only record the measured values for room atmosphere and aesthetics during the follow-up survey (T2). (Please contact Luca Bettinger, the corresponding author, at luca.bettinger@student.fhws.de for a copy of the questionnaires.)

Figure 6: Study procedure from recruitment to the analysis



Data analysis

We will collect the data with paper questionnaires that will be pseudonymised directly during the survey. An assignment of the questionnaires to the participants is only possible with the help of an identification list. We will then transfer the data to SPSS to carry out all analyses. After the data analysis, we will destroy the pseudonymised questionnaires and the identification list. It will therefore no longer be possible to assign data to participants. Only the two authors will have access to the data. In the context of descriptive statistics, we will calculate discrete variables as frequencies. On the other hand, we will give continuous variables as mean values, including standard deviation. We will calculate the baseline characteristics with one-factor analyses of variance (ANOVAs). We will calculate ANOVAs with repeated measures and between-subjects interaction to examine differences between the control and intervention groups (between-subjects factor) and the two measurement time points (within-subjects factor). We will also calculate single-factor ANOVAs to examine differences in room atmosphere and aesthetics.

TRIAL STATUS

At the time of submission, we have recruited no study participants. We registered the study a priori at the Center for Open Science.[28]

REFERENCES

1. Ritchie H, Roser M. Urbanization. Our World in Data [Internet]. June 2018 [cited 25 June 2022]; Available from: https://ourworldindata.org/urbanization
2. Montgomery MR. The Urban Transformation of the Developing World. Science. 8. February 2008;319(5864):761–4. doi: 10.1126/science.1153012
3. Riha J, Karabarinde A, Ssenyomo G, et al. Urbanicity and Lifestyle Risk Factors for Cardiometabolic Diseases in Rural Uganda: A Cross-Sectional Study. Razak F, Herausgeber. PLoS Med. 29. July 2014;11(7):e1001683. doi: 10.1371/journal.pmed.1001683
4. Ventriglio A, Torales J, Castaldelli-Maia JM, et al. Urbanization and emerging mental health issues. CNS Spectr. February 2021;26(1):43–50. doi: 10.1017/S1092852920001236
5. He S, Song D, Jian W yan. The Association between Urbanization and Depression among the Middle-Aged and Elderly: A Longitudinal Study in China. INQUIRY. January 2020;57:004695802096547. doi: 10.1177/0046958020965470
6. Gorrell S, Trainor C, Le Grange D. The impact of urbanization on risk for eating disorders. Current Opinion in Psychiatry. May 2019;32(3):242–7. doi: 10.1097/YCO.0000000000000497
7. Richter D, Löbner M, Riedel-Heller SG, Gühne U. Was wissen wir über die Zusammenhänge von Urbanisierung und psychischen Erkrankungen?: Ein systematischer Literaturüberblick. Psychiatr Prax. July 2021;48(05):231–41.
8. Cho SJ, Oh DH, Lee JA, et al. Prevalence of Main Psychiatric Disorders in Relation to Urbanization in Gyeonggi Province by Using the Korean Version of the Mini-International Neuropsychiatric Interview. *Journal of Korean Neuropsychiatric Association*. July 2016;50(4):288–96.
9. Song C, Ikei H, Miyazaki Y. Physiological Effects of Nature Therapy: A Review of the Research in Japan. IJERPH. 3. August 2016;13(8):781. doi: 10.3390/ijerph13080781
10. Choe EY, Jorgensen A, Sheffield D. Does a natural environment enhance the effectiveness of Mindfulness-Based Stress Reduction (MBSR)? Examining the mental health and wellbeing, and nature connectedness benefits. Landscape and Urban Planning. October 2020;202:103886. doi: 10.1016/j.landurbplan.2020.103886
11. Jeong JE, Park SA. Physiological and Psychological Effects of Visual Stimulation with Green Plant Types. IJERPH. December 2021;18(24):12932. doi: 10.3390/ijerph182412932
12. Beukeboom CJ, Langeveld D, Tanja-Dijkstra K. Stress-Reducing Effects of Real and Artificial Nature in a Hospital Waiting Room. The Journal of Alternative and Complementary Medicine. April 2012;18(4):329–33. doi: 10.1089/acm.2011.0488
13. Jiang M, Hassan A, Chen Q, et al. Effects of different landscape visual stimuli on

psychophysiological responses in Chinese students. Indoor and Built Environment. August 2020;29(7):1006–16. doi: 10.1177/1420326X19870578

14. Song C, Ikei H, Miyazaki Y. Physiological Effects of Visual Stimulation with Forest Imagery. IJERPH. 26. January 2018;15(2):213. doi: 10.3390/ijerph15020213
15. Kaya N, Epps H H. Relationship between color and emotion: A study of college students. College Student Journal, 2004; 38(3), 396–405.
16. Michels N, Debra G, Mattheeuws L, Hooyberg A. Indoor nature integration for stress recovery and healthy eating: A picture experiment with plants versus green color. Environmental Research. September 2022;212:113643. doi: 10.1016/j.envres.2022.113643
17. Park SH, Mattson RH. Ornamental Indoor Plants in Hospital Rooms Enhanced Health Outcomes of Patients Recovering from Surgery. *The Journal of Alternative and Complementary Medicine*. September 2009;15(9):975–80. doi: 10.1089/acm.2009.0075
18. Dijkstra K, Pieterse ME, Pruyn A. Stress-reducing effects of indoor plants in the built healthcare environment: The mediating role of perceived attractiveness. *Preventive Medicine*. September 2008;47(3):279–83. doi: 10.1016/j.ypmed.2008.01.013
19. Summerbell RC, Krajden S, Kane J. Potted plants in hospitals as reservoirs of pathogenic fungi. *Mycopathologia*. April 1989;106(1):13–22. doi: 10.1007/BF00436921
20. Rappe E, Lindén L. Plant in health care environment: experiences of the nursing personnel in homes for people with dementia. Acta Hortic. June 2004;(639):75–81. doi:10.17660/ActaHortic.2004.639.8
21. Ball P. Designed by nature: die Natur als genialer Gestalter. Darmstadt: Theiss; 2016. 288 S.
22. Faul F, Erdfelder E, Buchner A, et al. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behavior Research Methods. 2009;41, 1149-1160. doi: 10.3758/BRM.41.4.1149
23. Ochiai H, Song C, Ikei H, et al. Effects of Visual Stimulation with Bonsai Trees on Adult Male Patients with Spinal Cord Injury. *IJERPH*. 5. September 2017;14(9):1017. doi: 10.3390/ijerph14091017
24. Levenstein S, Prantera C, Varvo V, et al. Development of the perceived stress questionnaire: A new tool for psychosomatic research. *Journal of Psychosomatic Research*. January 1993;37(1):19–32. doi: 10.1016/0022-3999(93)90120-5
25. Fliege H, Rose M, Arck P, Levenstein S, et al. Validierung des “Perceived Stress Questionnaire” (PSQ) an einer deutschen Stichprobe. *Diagnostica*. July 2001;47(3):142–52. doi: 10.1026//0012-1924.47.3.142
26. Dalbert C. ASTS – Aktuelle Stimmungsskala. 2002 [cited 9. June 2022]; Available from: https://www.psycharchives.org/jspui/handle/20.500.12034/340.2
27. McNair DM, Lorr M, Droppleman LF. EITS–manual for Profile of Mood States. San Diego, CA: Educational and Industrial Testing Service.; 1971.
28. Bettinger L, Schweighart R. Psychological and physiological effects of visual stimulation with real plants and artificial natural structures. June 2022. doi: 10.17605/OSF.IO/T98VU

ACKNOWLEDGEMENTS

None

PEER REVIEW

Not commissioned. Externally peer reviewed.

CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

FUNDING

None

ETHICS COMMITTEE APPROVAL

All procedures in this study will be performed in accordance with the Declaration of Helsinki.