Final Report

Brilliant Marine Research Idea 2021

This report should be submitted **no later than 28 February 2022** via filantropie@vliz.be and consist of the following documents:

- A final report listing the work done and the problems encountered. This report will be made available online. If any of the tasks has not been completely finished, the report should clearly mention this, including a short explanation. **max. 5 pages**
- An overview of all expenditures including invoices.
- A set of five pictures (low resolution in this document). The five High Resolution pictures should be delivered to VLIZ by email to karen.rappe@vliz.be. Pictures should be free from use - to upload on the VLIZ website and to use in VLIZ communications.

Keep in mind that VLIZ should be mentioned in the acknowledgements of publications following the results of this Brilliant Marine Research Idea.

1. General information

Title of the idea	The NeXus-10 MKII for holistic insights in the physiological drivers behind mental health restoration from virtual coastal landscapes
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2. Brilliant Marine Research Idea – Report about the activities

Abstract
Natural environments, such as coastlines and green spaces, have been shown to improve indices of mental health more than urban or littered natural environments. However, it is still unknown whether coastal environments also alter physiological processes related to the stress-response, and how these effects differ from those of green, urban, and littered environments. Therefore, this study compared the physiological and psychological reactivity of beaches, beaches with litter, green spaces, and urban spaces. A randomized controlled cross-over experiment exposed each participant to two of these environments in virtual reality with sound (beaches and one other). Physiological measures included brain activity, cardiovascular functioning, respiration, muscle tension, skin conductance, and temperature, which were measured with the NeXus-10 MKII and software BioTrace+ from MindMedia

[1] We would also like to acknowledge the members of the expert committee involved in my PhD, who gave valuable contributions to developing this project: prof. dr. Robert Malina and Ilias Mokas of UHasselt, and prof. dr. Marie-Anne Vanderhasselt and Jens Allaert of UGent.

(acquired with the BMRI grant). Alongside physiology, psychological measures of interest included positive and negative mood (PANAS), cognitive performance (i.e. Stroop, DSB), perceived stress, perceived mental exhaustion, and perceived restorativeness. The participants were 164 healthy adults aged 18-65y, and recruited via a media-campaign (www.uitzicht.org). A series of generalized linear mixed models investigated whether reactivity of the physiology and psychology differed between the environments, while controlling for participant and study-design related covariates and random effects. The preliminary non-peer-reviewed results indicated that, compared to urban spaces, beaches decreased brain activity and respiration rate, and positively influenced psychological outcomes (e.g. mood and restoration, not cognitive performance). Compared to green spaces, beaches were associated with lower brain activity, lower negative mood, and better scores for attention inhibition. The presence of small representative amounts of litter resulted only in more negative mood and a lower perceived restorativeness, and not in differences in physiological reactivity. In conclusion, the NeXus-10 MKII purchased with this BMRI grant successfully measured the physiological reactivity in response to virtual coastal and other environments. Additional analyses on the acquired data are being done to refine the results further and publish them in a peer-reviewed article.
Keywords: Coast; Health; Virtual reality; Psychophysiology; Attention; Restoration

Intro

The health benefits of coastal environments have been increasingly investigated for their potential usefulness in nature-based therapies against poor mental health (White et al., 2016). That is because environments have been shown to improve people's emotional and cognitive states, such as reduced negative emotions, improved mood, a better working memory, and a better ability to focus and inhibit distractors (Gascon et al., 2015; White et al., 2020). However, there is still very little knowledge about the physiological responses, and it is anticipated that coastal environments alter the activity of the nervous systems that are responsible for various mental health outcomes (Vert et al., 2020), including the activity of the central, somatic, parasympathetic (PNS), and sympathetic (SNS) nervous systems. Therefore, the primary aim of this research was to investigate how the reactivity of these nervous systems differed in response to exposure to beaches, beaches with litter, green spaces, and urban spaces. More specifically, the reactivity of the nervous systems was measured by various physiological endpoints, including the electrocardiogram (ECG), blood volume pulse (BVP), respiration, electrodermal activity (EDA), brain activity (electroencephalogram, EEG), fingertip temperature, and muscle tension (electromyogram, EMG). This BMRI provided the necessary funding to obtain the NeXus-10 MKII from MindMedia, a device required for measuring human physiology. Alongside the physiology, a secondary aim was to detect differences in the reactivity of the psychological endpoints of interest, which were positive and negative mood, attention performance, attention inhibition, attention flexibility, perceived stress, perceived mental exhaustion, and perceived restorativeness.

Material & Methods

Study design: A randomized controlled cross-over virtual reality experiment exposed each participant to two virtual reality environments, with measurements done before, during and after both exposures. Each participant was exposed to the 'beach', and to one of the other environments, being 'beach with litter', 'green', or 'urban'. The order and allocation of the environments to the participants were semi-randomized and manipulated towards the end of the experiment to result in a balanced average age, sex ratio, and residential proximity to the coast between groups.

Recruitment and participants: The participants included 164 healthy Belgian adults aged 18-65y. Participants could not participate when being pregnant, chronically ill, on medication, sensitive to motion sickness, having impaired of sight or hearing, or being fearful for the ocean. Recruitment happened via 'Uitzicht' (dutch-to-English translation: 'an outlook'), a media-campaign with a website (www.uitzicht.org/nl) and Facebook-page (https://www.facebook.com/Uitzicht.onderzoek), that targeted people interested in research about the relationships between 'the environment' and mental

health (blinded for the exposures). The experiments were performed at the University Hospital of Ghent or at the Flanders Marine Institute (Ostend, Belgium), depending on the participant's preference. Two participants experienced motion sickness, and the physiological data of 36 participants was not valid due to technical, participant-related, or other interferences. The protocol was programmed and ran in the BioTrace+ software (MindMedia) that was accompanied with the NeXus-10 MKII (see further).

Virtual-reality exposures: Each virtual-reality session comprised of a 16-minute 360° video with sound that was shown through a virtual reality headset (Oculus Rift S) with a noise-cancelling headphone (Sony WH-1000XM3). Each video consisted of eight different two-minute scenes of the particular type of environment, which transitioned by fading-to-black. For the 'beach' and 'beach with litter' conditions, the scenes were filmed from the exact same locations without and with three beach-found litter items placed on the ground in a radius of approximately three meters from the camera, respectively. The videos were shot by the researcher with a GoPro Max 360° camera on 5K resolution (30 fps) mounted on a tripod at eye-level, during which the researcher sat in the vicinity (10-30 meters) to record high-quality sound with a Rhode VideoMicro microphone mounted on a Nikon D850 camera. The tripod and researcher were edited out in post-processing with Adobe After Effects and Adobe Premiere Pro.

Endpoints: Figure 1 gives an overview of the protocol, all the measured endpoints, and when these measurements took place.

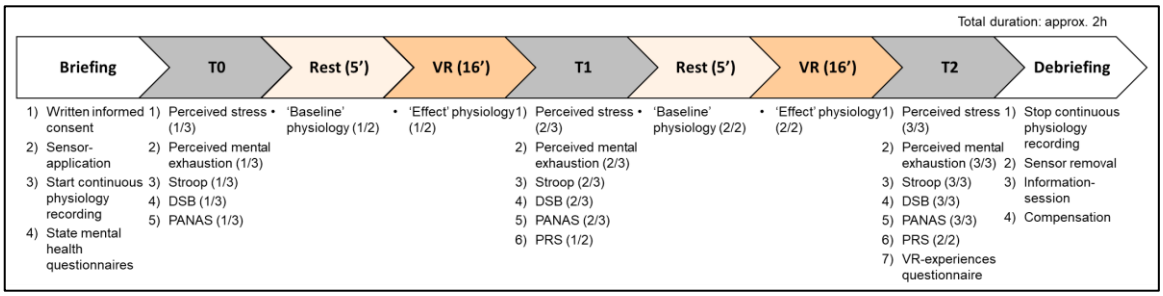

Figure 1: Overview of the experimental protocol, with the performed actions and measurements

Physiological endpoints of interest were derived from measurements by the NeXus-10 MKII and its sensors applied on the participant's body (Table 1). All data was recorded at a frequency of 512 Hz (cable connection, participant 1-42) or 256 Hz (Bluetooth connection, participant 43-164). After exporting the relevant indices from BioTrace+, they were loaded into in R (RStudio) and averaged per 'baseline' and 'effect' time period.

Table 1: Overview of the techniques, sensors, and indices used to measure the envisioned endpoints. Abbreviations: PNS = Parasympathetic nervous system, SNS = Sympathetic nervous system.

Technique	Analysed indices	Endpoint	Sensor application
Brain activity of the left and right frontal lobes (electro-encephalography, EEG)	Spectrally decomposed brain waves: delta (1-4 Hz, alertness), theta (4-8 Hz, daydreaming), alpha (8-10 Hz, relaxation), beta (13-21 Hz, directed attention), and gamma (35-45 Hz).	Brain state (central nervous system activity)	One bipolar sensor placed on the left hemisphere (F3 and C3 = reference). One bipolar sensor placed on the right hemisphere (F4 and C4 = reference). The skin was cleaned and prepped with NuPrep gel, and electrodes were attached with Ten20 paste.
Electrocardiogram (ECG)	Heart rate, heart rate variability (HRV), low and high frequency heart rate variability (LF and HF), and LF/HF ratio	PNS- and SNS-mediated vagal nerve activity	Two pre-gelled Ag/Cl electrodes placed below the participant's right clavicula and on the left bottom ribs.
Blood volume pulse (BVP)	BVP amplitude	SNS-activated vasoconstriction	Photoplethysmography (PPG) sensor clipped on the participant's distal phalange of the left ring finger.
Electromyography (EMG) of the left upper trapezius	Raw EMG signal	Somatic nervous system activity	Two Ag/Cl pre-gelled electrodes (diameter = 24mm) placed directly against each other along the muscle.

Electrodermal activity (EDA)	Raw EDA signal	SNS-activated sweat on the hands	Two Ag/Cl electrodes strapped with Velcro to the palmar side of the second digits of the left index and middle finger.
Respiration	Respiration rate and depth	Autonomic (SNS and PNS) and non-autonomic regulation	Stretch-sensitive sensor in an elastic belt placed around the participant's body in the region of the diaphragm.
Fingertip temperature	Raw temperature	Temperature regulation	Temperature sensor attached to the palmar side of the left little finger with cotton isolation and tape

Besides physiology, additional psychological measurements included positive and negative mood (PANAS), cognitive performance (Stroop for attention performance, attention inhibition, and attention flexibility, DSB for working memory), perceived stress (1 rating from 0 to 10), perceived mental exhaustion (1 rating from 0 to 10), and perceived restorativeness (PRS rated from 0 to 10).

Covariates: Covariates related to the participant's demographics, lifestyle, nature exposures, mental health, and personality were measured by various questionnaires before the start of the experiment, and factors related to the taking of the experiment (e.g. room temperature) were also considered.

Analyses: The analyses focused on whether the type of environment (beaches, beaches with litter, green spaces, urban spaces) had impacted the reactivity from 'baseline' to 'effect' for physiological measurements or from pre-VR to post-VR measurements for psychological measurements, where T1-measurements acted as both post-VR for the first exposure and pre-VR for the second exposure. For each analyzed index, one generalized linear mixed model was constructed with the interaction between baseline/effect or pre-VR/post-VR measurement and the type of environment as main predictor (beach as reference), with age, sex, and socio-economic status as covariates, and with individual and the order of the exposure as random effects.

Results/Conclusions

The non-peer-reviewed results suggest that the differences between environments mainly arose as changes in central nervous system activity (i.e. brain activity), mood, perceived stress, perceived mental exhaustion, and perceived restorativeness. Apparently, none of the indices for parasympathetic, sympathetic, and somatic nervous system activity differed in reactivity between the environments. More specifically, compared to urban exposure, beaches induced a significantly lower respiration rate ($B = 1.27 \pm 0.57$; $p = 0.03$), a lower brain activity (delta-left, theta-left, alpha-right, beta-right; gamma-left; $p < 0.05$), a higher positive mood ($B = -0.32 \pm 0.08$; $p < 0.01$), a lower negative mood ($B = 0.3 \pm 0.06$; $p < 0.01$), a lower perceived stress ($B = 1.96 \pm 0.3$; $p < 0.01$), a lower perceived mental exhaustion ($B = 1.52 \pm 0.3$; $p < 0.01$), and a lower perceived restorativeness ($B = -4.73 \pm 0.23$; $p < 0.001$). Compared to green spaces, beaches were associated with lower brain activity levels ($p < 0.05$), a lower negative mood ($B = 0.14 \pm 0.06$; $p = 0.02$), and a higher attention inhibition ($B = -2.2 \pm 1.01$; $p = 0.03$). The small representative amounts of litter only resulted in increased negative mood ($B = 0.16 \pm 0.06$; $p = 0.01$) and a lower perceived restorativeness ($B = -0.65 \pm 0.23$; $p = 0.01$), and not in an altered reactivity of the measured physiology.

Highlights and difficulties relevant for the BMRI: The data-acquisition by the Nexus-10 MKII was excellent and of research-grade quality, the use of the BioTrace+ software is highly user-friendly and already calculates some useful indices related to the stress-response (e.g. HRV amplitude), and the support of Mind Media was adequate and timely when needed (a small defect due to repeated usage of the device was repaired fairly quickly upon request). However, transferring the data from BioTrace+ to secondary software for additional pre-processing steps and analyses proved to be more difficult and time-consuming than initially envisioned. Therefore, the analyses and results presented in this report are based on the indices that were directly exported from BioTrace+, and our efforts continue to refine these results with analyses in secondary software, with the ultimate aim to have these results peer-reviewed and approved for publication.

Conclusion: The NeXus-10 MKII, purchased with this BMRI grant, successfully measured the physiological symptoms related to stress in a comprehensive VR-experiment. As such, detailed insights were gained about the joint influences of coastal environments on the different aspects of human health, which we compared to the effects of urban spaces, green spaces, and littered beaches. Analyses in secondary software will validate and refine these results further, and alternative approaches other than those presented in this report will test the coherence between outcomes (i.e. structural equation modelling) and the potential moderation by the participant's characteristics.

3. Overview of the expenditures

Describe in detail how the requested fund was spent within the implementation period (1 March 2021 and 28 February 2022). Be as specific as possible.

The received fund of 5.000,00 EURO was fully and immediately spent on Mind Media's NeXus-10 MKII and on the accompanied software (BioTrace+), biosensors, and consumables at the end of March 2021 from the company Mind Media (see invoice attached). The bench fee of my PhD covered the remaining costs from the biosensors and consumables. The products were delivered on May 22nd 2021. The equipment is already being used in future studies, and has been made available for lending as well.

4. Pictures

A set of five pictures (low resolution in this document). The five High Resolution pictures should be delivered to VLIZ by email to karen.rappe@vliz.be.




References

Gascon, M., Mas, M.T., Martínez, D., Dadvand, P., Forns, J., Plasència, A., Nieuwenhuijsen, M.J., 2015. Mental health benefits of long-term exposure to residential green and blue spaces: A systematic review. Int. J. Environ. Res. Public Health 12, 4354–4379. https://doi.org/10.3390/ijerph120404354

Vert, C., Gascon, M., Ranzani, O., Márquez, S., Triguero-Mas, M., Carrasco-Turigas, G., Arjona, L., Koch, S., Llopis, M., Donaire-Gonzalez, D., Elliott, L.R., Nieuwenhuijsen, M., 2020. Physical and mental health effects of repeated short walks in a blue space environment: A randomised crossover study. Environ. Res. 188, 109812. https://doi.org/10.1016/j.envres.2020.109812

White, M.P., Elliott, L.R., Gascon, M., Roberts, B., Fleming, L.E., 2020. Blue space, health and well-being: A narrative overview and synthesis of potential benefits. Environ. Res. 191, 110169. https://doi.org/10.1016/j.envres.2020.110169

White, M.P., Pahl, S., Wheeler, B.W., Fleming, L.E.F., Depledge, M.H., 2016. The "Blue Gym": What can blue space do for you and what can you do for blue space? J. Mar. Biol. Assoc. United Kingdom 96, 5–12. https://doi.org/10.1017/S0025315415002209