

## Article

# Physiological and Psychological Benefits of Exposure to Nature During Work in a Military Bunker—A Pilot Experimental Study

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## Abstract

The present controlled experimental research addresses the effects of exposure to nature on workers' well-being and job performance in a work-confined setting. Ten individuals working in an open-space office inside a Portuguese military bunker were exposed to simulated nature (audio sounds and/or video images of nature). Quantitative physiological (heart rate) and self-reported measures (perceived positive and negative emotions, environment restorativeness, and work performance) were taken. Results indicate that exposure to nature during working time in confined places, through simulating a window with a view of nature and/or by introducing sounds of nature, promotes physiological and emotional well-being at work (heart rate significantly decreases, positive emotions significantly increase, and negative emotions decrease), and significantly increases employees' perception of workplace restorative qualities. The results on work performance were non-significant. The present findings contribute to the evidence of the restorative effects of nature exposure during work. The research bridges a gap by considering workplaces where real nature exposure is not feasible and examining the evidence on the beneficial biophilic interventions (the restorative effects of simulated nature) within confined environments. The strategy to use videos and audio of nature may improve the structural conditions of work, benefiting well-being in these types of work settings.

**Keywords:** confined workspace; restorative environment; psychological well-being; work performance



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## 1. Introduction

Environmental features can be sources of stress for individuals or promote their recovery from stress [1]. Environments that allow for the restoration of cognitive–emotional and functional resources and capacities (physiological and psychological) that may have been compromised by stress or daily demands [2–4], are called restorative environments. Attention restoration theory [5] and stress recovery theory [6] support the notion that safe, natural environments are more restorative than non-natural settings [7]. Empirical findings support that natural environments are perceived as more restorative than urban environments [8], benefiting well-being and recovery from mental fatigue and emotional pressure [7,9–12], and have positive physiological impacts, such as blood pressure and heart rate regulation [13,14]. Urban green spaces also reveal restorative capacities, promoting the mental health and well-being of the urban population (e.g., anxiety and depression) [1,9,15–17].

Nonetheless, the naturalization of cities encourages the use of natural systems and processes in the design of the built environment [18–20]. The so-called biophilic design, a concept referring to the innate human need to connect with the natural world [21], besides addressing specific aspects of urban sustainability and ecological resilience [22], pretends to maximize natural lighting in buildings and the inclusion of natural components like water and plants, opportunities to increase exposure to nature, and to address the failure of modern indoor environments' design to accommodate nature-related human needs [18]. The biophilic design of built environments has been linked to improvements in the perceived restorativeness of the environment, physical health, and well-being [23–25]. It has received increasing attention for the design and re-design of workplaces [26].

Interior environmental conditions may affect employees' health and well-being, and most workers spend their working time indoors, within buildings [27,28]. In recent review studies, evidence emerged indicating that workplace stressors, such as noise, have cognitive, behavioral, emotional, and physical consequences for individuals, and negative implications for organizations, including low performance and absenteeism [29]. High levels of background noise and speech intelligibility in the workplace appear to negatively affect both physical and psychological well-being, causing higher fatigue, disturbance, and annoyance, and increasing physiological stress [30]. There is no clear association between noise level and task performance [31]. Open-plan or open-space offices have been around for more than half a century, chronicling such vicissitudes of workplace topography [32]. Working in open-plan offices is associated with more negative outcomes than working in traditional offices, including increased stress [33]. Associated characteristics of particular concern included noise and distractions, human voices, and phone ringing as being the most common distractors and sources of disturbance [34,35] that may cause fatigue and negatively affect work satisfaction, cognitive performance, interpersonal relationships, and well-being [34,36–38]. On the other hand, the literature supports the assumption that appropriate building characteristics for healthy work environments are cost-effective [39], and that workplace design could support recovery through promoting connection with nature [30,40]. Applying biophilic design to working environments may impact both individuals (promoting stress reduction and assisting in mental recovery) and organizations (increasing work performance and reducing absenteeism) [26]. Its implementation in open-plan offices has been shown to improve employee health and well-being, job satisfaction, productivity, and performance [41–46]. A recent systematic review [47] provided compelling evidence regarding the restorative effects of nature exposure in the workplace (including biophilic design), and a review on nature-based interventions in workplaces highlighted the positive impact on mental health and creativity [48].

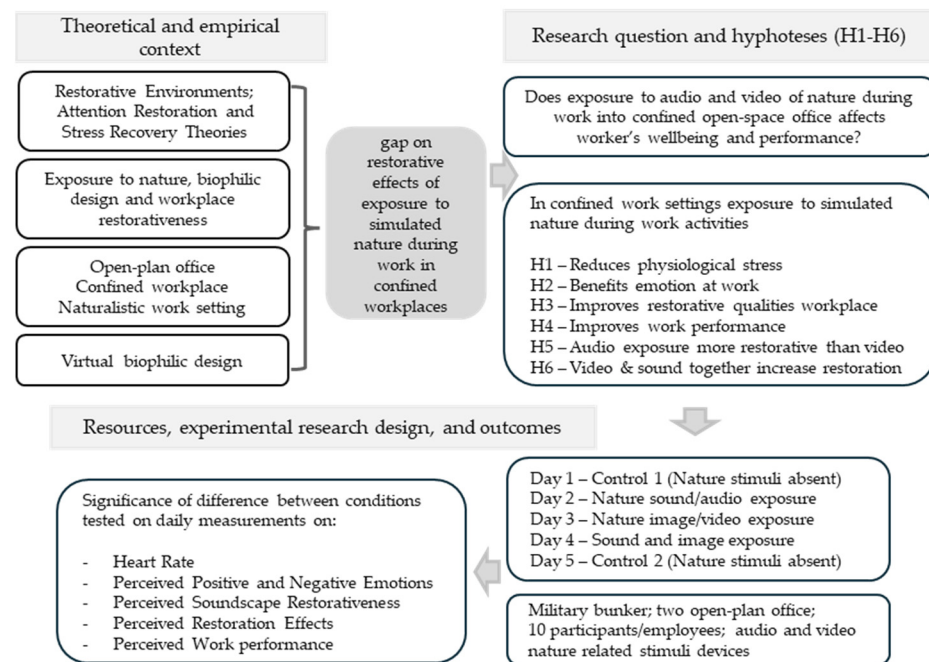
For reasons involving security, risk, and/or secrecy, certain activities or work tasks require confined environments, such as restricted operational settings like spacecraft or military installations, including bunkers and submarines, or closed systems with tightly coupled components, often operating within isolated environments [49]. Confined spaces usually lack natural ventilation, have restricted access and exit solutions, exposure to artificial light, and electronic devices are heavily used. The constant contact with an austere environment negatively affects individuals, with teams in isolated, confined, and extreme environments, such as in Antarctic or Arctic missions, facing many risks to health and well-being: workers' circadian cycles could be misaligned [49,50] and increasing demands to reduce the resources available to deal with them [51] negatively affect social relations and work performance [49,52–55]. Thus, bringing nature into austere and restrained environments has already been considered to be fruitful in stress reduction and improving work productivity [56], and biophilic design has been proposed to diverse types of confined workplace to create restorative work settings and enhance individuals' cognitive

function, well-being, work quality, and satisfaction, even in typically lean and minimalist, windowless, and monochrome break areas of military establishments [26]. Research on the interior architecture of artificial habitats that are used for space missions suggests the incorporation of “bionomic” design [57]: simple and cost-effective solutions to create more restorative environments and mitigate stress during long-duration space missions, and enhancing the crew’s performance and psychological functioning. Few empirical findings support the idea that access to nature may provide value within restricted and confined environments. Studies on prison settings found that there were positive effects of real and vicarious nature experiences both on inmates and carceral workers. Inmates in English prisons had attributed a range of positive outcomes to contact with nature, including increase in well-being, self-worth, and comfort, regardless of a person’s previous experience of nature [58]; nature videos provided for one year to American maximum-security prison inmates, housed in solitary confinement, increased feelings of well-being whilst reducing stress and aggression [54] compared to inmates who were not offered such videos. A national-level, statistically robust analysis of England and Wales highlighted that prisons with a higher proportion of natural vegetation within their perimeter have lower levels of carceral staff sickness absence [59]. Regarding the evidence from space habitats research, Mazhar et al.’s review [60] sheds light on the psychological and emotional benefits of having greenery in enclosed, isolated space habitats. Two studies, from Firth and Jayadas [61] and Winn et al. [62], that quantify the effects of the integration of biophilic design during a simulation of personal crew quarters on the International Space Station, found that nature virtual reality in spacecrafts and space habitats significantly improved emotions and cognitive responses when compared to the current design.

Individuals working indoors may be exposed to direct or indirect nature-related stimuli in the work setting, in addition to the possibility of having outdoor green breaks. Direct stimuli concern the physical presence of natural elements (e.g., water, plants, natural or “green” view), with “natural analogs” and other evocations, simulations, and representations of nature, such as paintings, photographs, videos, and audio, being considered indirect stimuli [26,63]. In certain indoor settings, where direct nature-related stimuli, the presence of real, physical natural elements, are not possible at all, biophilic principles applied by virtual reality present unique opportunities to bring nature, indirectly, into restricted or confined settings [64,65]. Natural stimuli through virtual reality had already been used to promote well-being in indoor, built environments [66,67]. From systematic reviews emerge evidence on virtual stimuli of nature in built settings that enhance spatial perception, physiological, psychological, and cognitive aspects that support attention restoration and stress reduction theories [68], and, specifically, that stimuli such as virtual forests, beaches, and water, promote well-being at the workplace [69].

Findings on the restorative benefits of nature exposure upon workers during work activities are limited, and developing more comprehensive investigations into the effects of nature in the workplace could contribute to consolidating the current knowledge and guiding more effective design strategies to create healthier and more productive workplaces [47]. There is a lack of empirical studies about restoration in confined workplaces. More findings could support solutions to promote the restoration of workers’ internal resources during work. The present study aims to contribute toward evidence on the restoration effects upon workers exposed to nature during work activities in their naturalistic work settings, and aims to bridge a gap by considering confined workplaces where real nature exposure is out of the question (Figure 1). The study sought to explore the restorative effects of exposure to simulated nature on workers from a confined workplace (military bunker) during their work activities, focused on stress and well-being-related physiological (heart rate) and psychological outcomes (perceived emotions and perceived restorative qualities

of the workplace), and on work performance. Research questions include: Does exposure to simulated/virtual sounds and images of nature during work activities in a confined open-space office have positive impacts on workers' heart rate, perceived positive and negative emotions, perceived restorative qualities and restorative effects of the environment, and work performance? Which type of stimuli is more restorative: virtual soundscape, virtual landscape view, or both together? Accordingly, six hypotheses have been tested in a controlled experiment (Figure 1).



**Figure 1.** Combined diagram of the study's theoretical and empirical context, research question and hypotheses, and controlled experimental design and outcomes.

**Hypothesis 1.** *Exposure to simulated nature at the work setting reduces physiological stress.*

**Hypothesis 2.** *Exposure to simulated nature benefits perceived emotions at work.*

**Hypothesis 3.** *Exposure to simulated nature improves perceived restorative qualities of the confined work setting.*

**Hypothesis 4.** *Exposure to simulated nature improves work performance.*

**Hypothesis 5.** *Exposure to a simulated nature soundscape during work is more restorative than exposure to a simulated view of nature.*

**Hypothesis 6.** *Exposure to both virtual nature sounds and images simultaneously is more restorative than exposure to sounds or to images.*

We discuss the implications of the results in the context of the benefits for both individuals (workers) and organizations.

## 2. Materials and Methods

The study results from an agreement signed between the Portuguese Air Force and the University of Algarve, and received approval from the Algarve University Ethics Committee Board and the Data Protection Officer. Participants have been informed about

the study's aim and procedures, as well as its confidentiality, and signed an informed consent form.

The experimental study took place in a naturalistic work environment (workers in their workplace setting): two small open-space offices located in a military bunker, a confined, closed space, without any contact with open air, without windows, and without natural lighting (Figure 2). The military installation, located on the top of a mountain, is surrounded by natural greenery.



**Figure 2.** Views of the military (bunker) installation indoor design and experimental setting (open-space office); on the office wall, front to workers' (study participants) desks, the simulated nature view is displayed in a plasma monitor.

The sample consists of a group of ten individuals (6 male, 4 female), all military and civilian workers from the Portuguese Air Force (Radar Station 1), with a mean age of 32 years ( $SD = 12.6$ ). Participants lived outside the military installation, in rural or semi-rural areas, and had a typical working day schedule from 9:00 to 18:00, with a lunch break.

The experimental study ran for five consecutive working days; each day corresponds to a different experimental condition. Two days were used as controls (no changes introduced to the office setting): the first day and the last (fifth) day, respectively, were designated as Control 1 and Control 2. The soundscape and visual work setting were manipulated during the other days: sounds of nature were introduced on the second day (sound condition); a simulated window with a nature view was introduced on the third day (video condition); and both video and sound were present on the fourth day (video and sound condition)—Figure 1. Nature stimuli consisted of a simulated window showing a natural landscape view, with green trees waving in the wind, a lake and mountain in the background, and across the day, the gradual natural daily change in light (Figure 2), by video projection using a plasma monitor on the wall that could be seen by every office worker, associated with an audio system. For the sound condition (day 2), the video system was off, and only the audio system emitted nature sounds. The sounds of nature had high auditory definition (48 KZ), dominated by running water and wind-related sounds, and small amounts of birdsong. Video condition (day 3) only involved projecting the video (sound system off). During day four, sound and video stimuli were presented simultaneously (same audio and video)—Table 1. Participants' exposure to sounds and video was about 6 h per day. The first day of the study (Control 1) and the three exposure to nature days were consecutive days of a work week with special events in the military bunker (including the annual "Open Day"), which added additional stress and fatigue compared to the usual working days at the bunker. Control 2 corresponded to a regular or usual working day in the following week, when additional stress factors were no longer present.

**Table 1.** Main features of the confined work environment—soundscape and visual setting, and mean air temperature and humidity—by experimental condition.

	Soundscape Human Voices, Keyboard Typing, Phone Ring	Sounds of Water, Rain, Wind, Birds	Visual Setting Metal Furniture, Devices, Gray Walls, Artificial Light	“Window’s Natural View”	Temperature and Humidity
Control 1	✓		✓		21 °C 55.5%
Sound	✓	✓	✓		21 °C 55.5%
Image	✓		✓	✓	21 °C 55.5%
Sound and Image	✓	✓	✓	✓	21 °C 55.5%
Control 2	✓		✓		21 °C 55.5%

Office environmental conditions have been regulated, with the room temperature and relative air humidity remaining constant during the five-day experience (mean temperature approximately 21 °C and relative humidity approximately 55.5%)—Table 1.

Quantifiable measures of restoration are crucial for understanding how restorative mechanisms function [70]. The present research has relied on physiological and self-reported measures as outcome variables in trying to assess the buffering effects of nature exposure among stressed or mentally fatigued workers.

Stress affects several physiological processes in the human body. The trigger in the autonomic nervous system, the parasympathetic nervous system suppression, and the sympathetic nervous system activation, lead to, for example, increased blood pressure and heart rate, and thus, heart rate is considered a physiological indicator of stress [71]. Concerning physiological measures, heart rate had been measured twice a day in beats per minute, using smartwatches: (1) by the end of the morning and before lunch break (around 13 h), and (2) before the end of the working day (close to 17 h). A daily mean value was calculated for each of the five days’ experience.

Self-reported measures were collected through a questionnaire completed by participants at the end of each of the five working days of the study, to assess individuals’ positive and negative emotions at work, work performance, the restorative potential of the soundscape, and the restorative effects of the environment. On the first day, participants also responded to questions about their socio-demographic characteristics, including age, gender, literacy, employment status (civilian or military), and place of residence (urban or rural).

Positive and negative perceived emotions are indicators of well-being. Mostly, people work within a social context and therefore, emotions play an essential role during working time, individual interactions, and organizational behavior [72]. To assess emotions, a Portuguese version of the Job-Related Affective Well-Being Scale (JAWS) was used. JAWS is one of the most widely used instruments for studying emotions at work. The original version, developed by Katwyk et al. [73], attempts to measure the frequency with which individuals experience 30 different positive and negative emotions at work. The first Portuguese version, from Ramalho et al. [74], was composed of 28 items (15 negative and 13 positive), had a bifactorial solution, and good psychometric qualities. Later, López et al. [72] revalidated a JAWS 20-item Portuguese version with a bifactorial solution (10 negative emotions and 10 positive emotions), which was used in the present study, yielding

good reliability (Cronbach's  $\alpha$  of 0.81 for positive emotions and 0.89 for negative emotions in the present sample).

To assess the potential changes in the perceived quality of the work environment by employees, two measures were used: the restorative potential of the sound-based environment and the perceived restorative effects of the environment. The perceived ability of an environment, setting, or landscape to provide psychological restoration—the way an individual perceives the restorative potential of a place—is considered a psychological construct. Hartig et al. [75] developed an instrument called the Perceived Restorativeness Scale to measure four theoretical qualities of the environment considered generators of individuals' restorative qualities: fascination, being away, compatibility, and extent. Based on the same idea, Payne [76] developed a similar instrument to measure the perceived quality of the surrounding sound for providing psychological restoration, known as the Perceived Restorativeness Soundscape Scale (PRSS): a 10-item scale, with a bi-factorial solution and an acceptable consistency (Cronbach's  $\alpha = 0.7$ ) [76]. Later, Payne and Gustavino [77] revised the PRSS and published the 9-item version, scored by a 7-point Likert-type scale, with a unifactorial solution and high consistency (Cronbach's  $\alpha = 0.88$ ), which was used in the present study. By a translation and back-translation procedure, a Portuguese version was obtained. According to the present data set, the Portuguese version of PRSS shows high consistency (Cronbach's  $\alpha = 0.97$ ).

Changes such as relief from mental fatigue and emotional stress are the expected effects of experiences that occur in restorative environments. The changes, referred to as restorative effects, may involve physiological, emotional, cognitive, and behavioral regulation, such as the recovery of attention capacity, reduced tension and increased relaxation, a more positive mood and affect, and a reduction in worries and chaotic thinking [78]. The Restoration Outcome Scale (ROS) from Korpela et al. [78] pretends to measure the perceived effects of restorative experiences. The 6 items, rated on a 7-point Likert-type scale (1 = not at all; 7 = completely), reflect feelings of relaxation and calm (e.g., "I feel calmer after being here"), attention restoration ("my concentration and alertness increase here"), and mental clearing ("visiting this place helps me forget everyday worries"). The scale has a unifactorial solution with very good internal consistency (Cronbach's  $\alpha = 0.92$ ). A Portuguese version of ROS, from Sousa et al. [79], was used to assess perceived restorative effects, presenting high internal consistency (Cronbach's  $\alpha = 0.97$ ) in the present study.

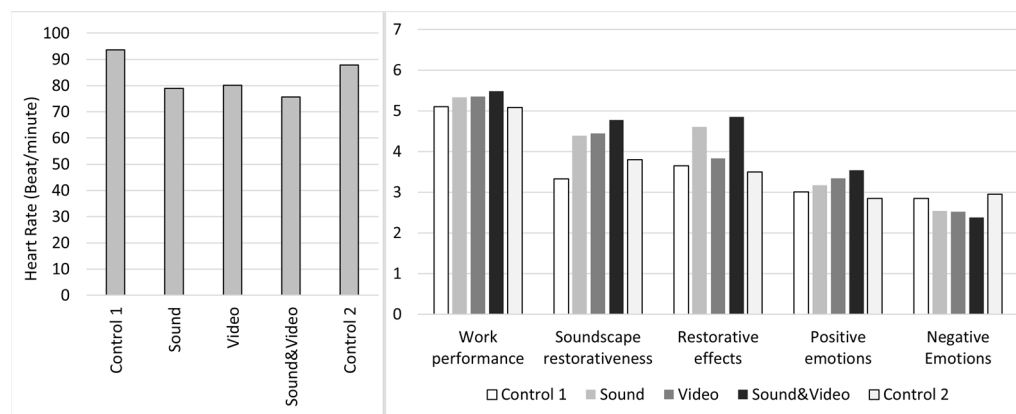
There is no clear definition of work productivity, especially when work is composed of a set of different tasks that characterize office work [80]. Work productivity is mainly assessed by perceived or self-reported work performance [45]. In the present study, work performance was assessed by the Portuguese version of the four-item scale developed by Rego and Cunha [81], using a 7-point Likert-type scale to rate answers, and presented adequate internal consistency (Cronbach's  $\alpha = 0.77$ ). In the present study, a Cronbach's Alpha of 0.64 was obtained for this measure.

Due to the small sample size, non-parametric tests were used to test differences between conditions (days), although the studied variables tend to manifest a normal distribution. The Friedman test for paired samples was used to determine if there was a significant difference among conditions, and the post hoc test was used to identify differences within conditions. Analyses were performed using IBM SPSS Statistics v. 30 (IBM, New York, NY, USA).

### 3. Results

Changes in work setting conditions, i.e., the presence of simulated nature on the workplace, impacted the outcome variables (Figure 3), with significant differences among studied conditions on heart rate ( $p = 0.001$ ), positive emotions ( $p = 0.001$ ), negative emotions

( $p = 0.004$ ), perceived soundscape restorativeness ( $p = 0.002$ ), perceived restorative effects of the environment ( $p = 0.002$ ), and exception to work performance ( $p = 0.171$ )—Table 2.



**Figure 3.** Mean values of the outcome variables by experimental condition.

**Table 2.** Outcome variables’ mean values (M), standard deviation (SD), and significance of the differences among studied conditions ( $p$ -values).

	Control 1 (M ± SD)	Sound (M ± SD)	Video (M ± SD)	Sound-Video (M ± SD)	Control 2 (M ± SD)	$p$ -Value
Heart Rate	93.65 ± 5.93	79.00 ± 12.01	80.20 ± 10.48	75.70 ± 8.92	87.90 ± 6.48	0.001 *
Posit Emo	3.01 ± 0.27	3.17 ± 0.30	3.34 ± 0.36	3.54 ± 0.28	2.85 ± 0.44	0.001 *
Negat Emo	2.85 ± 0.47	2.54 ± 0.53	2.52 ± 0.53	2.38 ± 0.64	2.95 ± 2.30	0.004 *
Sound Rest	3.65 ± 1.57	4.61 ± 1.33	3.83 ± 1.47	4.85 ± 1.02	3.50 ± 0.84	0.002 *
Rest Effect	3.33 ± 1.28	4.39 ± 1.20	4.45 ± 1.41	4.78 ± 1.00	3.80 ± 1.19	0.002 *
Work Perf	5.10 ± 0.64	5.33 ± 0.58	5.35 ± 0.88	5.48 ± 0.63	5.08 ± 0.78	0.171

Posit emo = perceived positive emotions; negat emo = perceived negative emotions; sound rest = perceived soundscape restorativeness; rest effect = perceived restorative effects of the environment; perf = performance; \*—very significant differences or Friedman test for paired sample  $p$ -value < 0.005.

The significant decrease in participants’ mean heart rate during nature exposure conditions compared to the controls supports the first study’s hypotheses that exposure to simulated nature at the confined work setting reduces physiological stress ( $p$ -values < 0.001–0.05)—Table 3. Perceived negative emotions at work were found to significantly decrease during exposure to nature compared to the controls ( $p$ -values 0.009–0.05), regardless of the type of nature-related stimulus (audio, video, or both), whereas an increase in positive emotions was significant only for the sound and video condition ( $p$  value < 0.008) when compared to both controls—Table 3. Overall, the results for perceived emotions indicate that exposure to simulated nature benefits perceived emotions at work, confirming Hypothesis 2. Compared to the controls, soundscape restorativeness increases for the sound ( $p$ -value < 0.047) and sound and video exposures ( $p$ -value < 0.028), and significant increases were found in perceived restoration effects between nature exposure conditions and Control 1 ( $p$ -value = 0.001–0.019), which was non-significant compared to Control 2. These results indicate the beneficial impact of exposure to simulated nature on perceived restorative qualities of the confined workplace, confirming Hypothesis 3. Results for the effect on work performance, the non-significant increase under nature stimuli, did not lead to confirmation of Hypothesis 4.

**Table 3.** Significance of the differences (*p*-value from post hoc analysis) between pairs of experimental conditions on outcome variables.

	Heart Rate	Positive Emotions	Negative Emotions	Soundscape Restorative	Restorative Effects
Control 1 × Sound	0.006 *	0.795	0.038 *	0.024 *	0.019 *
Control 1 × Video	<0.001 **	0.100	0.024 *	0.759	0.015 *
Control 1 × Sound and Video	<0.001 **	0.003 **	0.009 *	0.007 *	0.001 **
Sound × Video	0.603	0.166	0.862	0.046 *	0.931
Sound × Sound and Video	0.119	0.007 *	0.603	0.665	0.225
Video × Sound and Video	0.299	0.194	0.729	0.015 *	0.260
Control 1 × Control 2	0.005 **	0.362	0.646	0.593	0.096
Control 2 × Sound	0.017 *	0.074	0.032 *	0.047 *	0.126
Control 2 × Video	0.022 *	0.036 *	0.044 *	0.258	0.058
Control 2 × Sound and Video	0.050 *	0.008 *	0.050 *	0.028 *	0.074

\*—significant difference or  $p < 0.05$ ; \*\*—very significant difference or  $p < 0.005$ .

Non-significant differences in heart rate and negative emotion between the different nature exposure conditions were found. Positive emotions associated with sound and video exposure were significantly higher compared to sound exposure ( $p = 0.007$ ). Both sound-related conditions revealed similar soundscape restorativeness, which were significantly higher than the video condition ( $p$  value = 0.046 and 0.015). On perceived restoration effects, similar significant increases were observed by different nature exposure conditions—Figure 3 and Table 3. The observed difference across conditions related to nature support both Hypothesis 5 and 6, indicating that exposure to a simulated nature soundscape during work could be more restorative than exposure to a simulated view of nature, although exposure to both virtual sound and images of nature simultaneously looks to be more restorative.

Overall, results support that nature in its virtual form could benefit restoration in workplaces where direct nature stimuli exposure is not possible at all. During work in a confined open office setting, nature stimuli as a simulated window with a natural landscape view or surrounding audio nature sounds, or both, proved to benefit workers' physiological and emotional well-being, while improving the perceived restorative qualities of the confined workplace. Exposure to sound, images, or both should have similar benefits; however, a nature-related audio stimulus was revealed to be slightly more restorative than a simulated window view, and simultaneous exposure to sounds and images was slightly more restorative than exposure to the audio or the images independently. No changes were observed in work performance in relation to exposure to virtual nature during work in the bunker.

#### 4. Discussion

This study focuses on the impact of simulated nature on workers' well-being in a small, windowless military bunker, by employing an experimental design (introduction of audio and visual stimuli of nature, with a control). As expected, the results support that nature in its virtual form could benefit restoration into workplaces where direct nature stimuli exposure is not possible at all. During work in a confined open-office setting, nature stimuli as a simulated window with a natural landscape view, or surrounding audio nature sounds, or both, proved to benefit workers' physiological and emotional well-being, while improving the perceived restorative qualities of the confined workplace. These findings highlight the importance of considering virtual nature in confined workplaces where nature exposure in its actual form is out of the question, providing evidence for biophilic interventions within extreme environments.

The research relies on both quantitative physiological (heart rate—HR) and subjective psychometric measures to compare conditions, to provide a multi-dimensional measure of outcomes. Concerning the physiological outcome, employees' heartbeats significantly decreased during conditions corresponding to exposure to nature, compared to conditions representing the current workplace environment (without simulated nature). By consistently indicating a positive physiological effect that is similar, regardless of the specific type of stimulus (audio, visual, or both), HR results are strong evidence of the benefits on workers' well-being from being exposed to simulated nature during work in the confined bunker. This finding aligns with previous research on HR response to stress [82], and on the relaxing and calming effects of nature-related workplace design on workers [83,84], although previous studies about confined spacecraft did not find significant differences in HR between biophilic and current design [61,62]. In addition, we also found significant differences in heart rate between the two controls and the two days of experience corresponding to the absence of a nature-related stimulus at the confined office, with higher heartbeat values observed for Control 1. Since Control 1 corresponded to an especially stressful work situation (special events at the military bunker) and Control 2 corresponded to a regular working day (without additional stress factors), this result points out the sensitivity of heartbeat as an indicator of stress (higher HR values associated with higher-stress working days). Considering that the three days corresponding to nature exposure's experimental conditions also corresponded to especially stressful working days in the bunker, HR significantly decreased during these days, which is further evidence of physiological stress regulation being induced by simulated nature-related stimuli on the bunker's workers.

Higher physiological stress causes a faster heart rate and changes in heart rate variability (HRV), with HRV reflecting the balance between the functioning of the sympathetic and parasympathetic branches of the autonomic nervous system [85]. HRV is widely used as an accurate short-term measurement related to stress, calculated from an electrocardiogram (ECG) standard device, which is mostly considered to be a measurement that does not place as high requirements upon the experimental design as other physiological measures, such as hormone levels, do. However, ECG use was not suitable for the present study, due to restrictions on practical issues, such as participants' working time consumption and restrictions on research financial support (no funding study). HR is also a non-invasive and easy-to-use stress measure and could be measured by portable electronic devices (smartwatch). In line with the increasing trend in the use of smartwatches to collect health and well-being-related data [86], the use of smartwatch devices made it possible to acquire physiological outcomes (HR) in the present study. However, investigation into smartwatch accuracy of HR vital signs measurements, compared with standard devices (ECG), is not conclusive enough. Most device models' HR measurements appeared to meet the pre-defined accuracy guidelines [87–89], varying with activity level [90,91]. Mean absolute percentage errors in HR measure varied between 3.1% and 8.3% for 10 different smartwatch models [92]. Different smartwatch model devices were used in the present study, due to logistic-related issues (each participant used their own device), possibly affecting HR measurement accuracy differently across participants. Thus, the overall accuracy of present HR estimates may be questionable, the percentage of error could be considered less than 10% [89,92], and higher percentages of change between the controls and nature exposure conditions have been observed in the present study. Additionally, considering that each device error remains similar across time, differences between devices' effect on results (comparison between conditions) should be small. Future investigations should carefully consider the accuracy of devices by selecting the most accurate model to be used by all participants.

Results on perceived positive and negative emotions at work corroborate the beneficial effects on well-being through exposure to nature in a confined work environment, compared to the usual/current confined workplace setting. The opportunity to experience virtual restorative environments has already been shown to mitigate the negative effects of stress on emotions and promote emotional regulation at work [68,70,93,94]. The effect on negative emotions, which was a significant decrease during exposure to nature, regardless of the type of nature-related stimulus, was clearer than the increase in positive emotions (a clear effect was observed only when combining the projection of a window with a nature view with the corresponding audio stimulus). More significant effects of the simultaneous presence of visual and auditory nature-related stimuli at the workplace on outcome variables have already been found [95]. Audio used in the present study had sounds of nature dominated by running water and wind blowing, with small amounts of bird sounds, which are referred to as having high potential to promote cognitive distancing from stress. Hedblom et al. [96] found no significant difference in soundscapes related to stress and physiological recovery, although bird sounds are characterized by higher frequency vibrations than wind or water sounds, and the human ear perceives high-frequency sounds as more “annoying”. Noise perception may be influenced by subjective personality traits [97], and the stress-reducing effect of listening to water sounds also appears to depend on interindividual differences [98], which may have affected perceived emotions at the bunker.

Dose, i.e., the amount or duration of exposure, may also have affected the employees’ emotional response to virtual nature in the bunker. Some authors consider it inappropriate to define normative nature dose–response frameworks [99]; however, others showed that the dose of nature is important in promoting healthy outcomes. Associations were found between the duration, frequency, and intensity of exposure to nature and mood [100]. The restoration of an individual’s internal resources during work breaks, designed as recovery breaks [101], is effective in reducing stress in the workplace [102]. An employee looking, from time to time, at a natural view through a simulated window could be seen as taking a deliberate or inadvertent short break, allowing for the restoration of internal resources during work. For images, the dose, the amount of exposure, or the duration of the break may have been regulated by the individuals. However, regulating the dose of sound for study participants may have been a more difficult task. In work settings, nature dose–response relationships and the role of personal agency warrant further attention [103]. Both may have affected the present results on emotions at work, and eventually the significance of the overall results. The dose or amount of nature exposure in confined workplaces requires further investigation.

Present results on perceived soundscape restorativeness confirmed that employees perceive the confined open-space office as having more restorative qualities when nature-related sound stimuli were presented. Whether alone or in conjunction with visual stimuli, virtual sounds of nature increased the perceived restorative qualities of the soundscape compared to the current non-exposure condition, whereas exposure to only images did not impact soundscape perception, as expected. The perception of the restorative effects of the work environment significantly increased during exposure to nature compared to Control 1, although the increase became non-significant when compared to Control 2. Despite these non-conclusive results about perceived restorative effects, the results of soundscape restorativeness pointed to the expected improvement in perceived restorative qualities of the confined work setting during exposure to nature. The restorative qualities of natural environments are well-documented by systematic reviews and meta-analyses, e.g., [8,104], including exposure to virtual nature, e.g., [93], in which the interaction between audio and visual stimuli increases feelings of immersion and presence, affecting the employees’ perception of the qualities and effects of work setting configuration [91]. The masking

effect of nature sounds [88] in the participants' auditory work setting should explain the increasing perceived qualities of the setting soundscape during sound-related nature exposure conditions.

Results were non-conclusive (nonsignificant improvement) regarding the beneficial effect of virtual nature exposure on work performance in a confined workplace. Natural elements in the workplace have been linked to benefits for both workers and organizations; however, according to Gonçalves et al.'s systematic review [47], empirical results for the effects on productivity and worker performance are inconclusive. Thus, the present study results for work performance align with the literature. Further investigations into the subject are needed.

Except for work performance, overall, the present results confirm the physiological and psychological restorative effects of being exposed to virtual nature in a confined workplace. The multi-dimensional overview of outcomes helped to consolidate findings on the benefits of using virtual nature in confined workplaces. However, results have limited generalization due to the small sample size. Collecting enough data to test hypotheses is often difficult for researchers, especially when it concerns small target groups that are hard to access, or when data collection entails prohibitive costs, which are the main obstacles that may result in small data sets [105]. Limitations associated with small data sets (i.e., simplified statistical models) may leave the "true" research questions unanswered and restrict the usefulness of the scientific conclusions. Although it is controversial, with the number for a small sample size ( $n = 30, 20, \text{ or } 10$ ), caution is needed when interpreting results from small sample studies [106]. Sanchez et al. [45] conducted a pilot experiment to assess the impact of biophilic design features on intellectual performance and well-being, which was carried out in a laboratory environment with a small group of eight participants (college students). The present study was conducted in a naturalistic workplace environment (not a laboratory experiment), a confined workplace with a limited number of employees, and very restricted access. Obtaining permission to study the Portuguese military bunker was a hard, time-consuming, challenging task. Access to the military confined workplace for the development of the present research was made possible by a unique opportunity window, and the study was conducted as a pilot experiment, intended to be replicated at other military bunkers. However, military safety and secrecy issues will continue to make it difficult to increase the sample size. Adequate non-parametric statistical testing was used, and the experiment was double controlled (two controls, before and after the experiment, and both used for statistical testing purposes), although the small sample size should be considered the major limitation of the study, with further research requiring a larger number of participants to improve the statistical power and reliability to allow the generalization of findings. Future research on exposure to nature in confined workplaces may also focus on aspects such as nature exposure dose and different types of visual and sound nature-related stimuli, may explore the effect of the type of office by using a control group (for example, a group of workers from confined closed offices), or explore the influence of personality traits or mental health issues in exposure to nature outcomes.

Mostly, workplaces, and specifically confined work settings, have been designed primarily for efficiency and safety, and are less focused on the occupants' physiological and cognitive health, and biophilic design could help ensure the well-being of employees [72,73]. Besides fragilities and limitations, the present study's practical significance is that the implementation of simple, inexpensive strategies, such as the introduction of nature sounds and/or the projection of nature-related videos, into confined workspaces may benefit the quality of the workplace and the well-being of employees. Virtual-related design solutions may also be applied to other domains or scenarios, to other enclosed environments such as underground workplaces, or even to non-confined workplaces, where the presence of

real nature is not possible at all. The results also suggest that exposure to simulated nature at the workplace could be a helpful solution during especially overcharged and stressful organizational moments, thus extending the application to a larger variety of work-related and other indoor settings, such as hospitals and prisons, to give a few examples.

## 5. Conclusions

This paper addresses the call to improve occupational health and well-being during work in confined environments, and aligns with the workplace biophilic design-related literature. It reports an experimental study of the impact of simulated nature experiences, focusing on workers' physiological and psychological well-being in a small, windowless military bunker, employing an experimental design with the introduction of audio and visual stimulation of nature on alternate days, with control and experimental conditions to compare heart rate, affective state, perceived restorative environment, and work performance. The results indicate that exposure to simulated nature by introducing nature sounds and projection of a "window with a view of nature" at a confined workspace (open space-office located in a bunker) benefits physiological well-being and perceived emotional state, and increases employees' perceived restorative qualities of the environment during work activities. The results are not conclusive regarding the effect on work performance. Results also indicate that exposure to simulated nature benefits employees during especially stressful working days. The research bridges a gap by considering confined workplaces where direct nature exposure during work is out of the question, and the evidence for virtual biophilic interventions within confined and extreme environments. It highlights how simple solutions, such as simulations of nature (images, sounds, or both), could bring restorativeness into confined workplaces. Virtual-related design solutions may also be applied to other domains or scenarios, such as enclosed environments like underground workplaces, or even to non-confined workplaces, where the presence of natural elements is not feasible. Because exposure to simulated nature has been indicated to be beneficial, especially during overcharged and stressful working events, the application may be extended to a larger variety of work settings (i.e., hospitals) and other indoor settings (i.e., prisons).

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author, due to restrictions related to military secrecy (non-disclosure of data on the socio-demographics of study participants, who were part of the staff of a military installation).

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