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Nature and City Sounds Influence Physiological and Psychological Markers in College Students

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Abstract

Worldwide, human population growth has led to a higher demand for urbanization. While this development is in accordance with our gregarious lifestyles, our availability and contact with nature has consequentially been minimized. The goal of this study was to evaluate whether sounds from nature versus urban environments affect vital signs (i.e., heart rate and respiration rate) and mood states of female college students. Emotional states were assessed using the Positive and Negative Affect Schedule (PANAS) questionnaire. While nature sounds included a mixture of birdsongs and water sounds, urban sounds included traffic, construction, and sirens. Following a within-subject design, each participant listened to a 7-minute segment of nature sounds and a 7-minute segment of city sounds in a randomized order. Sounds were played through each participant's own headphones and devices at a conversational volume of approximately 70 decibels. All dependent variables were recorded before and after listening to each type of sound. This study was performed throughout the COVID-19 pandemic (April-August 2020). To comply with health and safety guidelines, each participant met with the experimenter through a WebEx virtual conference, and variables were self-recorded by each of the participants. Exposure to 7-minutes of sounds from a natural environment resulted in statistically significant decreases in both respiration rate and negative affect schedule score when compared to the same time exposure to urban sounds. Furthermore, participants had a significantly higher preference for natural over urban environments according to a survey performed prior to listening to both types of sounds. Future research could help to better understand causes for variability in human responses to sound stimuli.

Keywords
Nature; city; urban; sounds; forest bathing; PANAS; environment; psychophysiology

1. Introduction

There has been a growing world-wide interest in enhancing our relationship with nature in the past few decades. Originating almost 40 years ago in Japan, the practice of "shinrin-yoku," translating to "forest-air bathing," relates to the experience of individuals immersing into a natural environment [1]. This activity is broadly thought to increase our overall wellness [2, 3]. Forest bathing is still a relatively new research topic, and the scientific and medical communities are beginning to ascertain how to implement shinrin-yoku as a natural, wellness medicinal approach [4, 5].

There are a few challenges related to the modern world that may interfere with humans' potential for reconnecting with nature. Access to natural areas with plants and wildlife may be difficult to find; especially, for individuals living in metropolitan areas [6]. According to the United States 2020 Census, 80.0% of the population lives in an urban area or cluster [7]. When compared against each other, individuals in a forest setting have significantly lower risks of cardiovascular disease than those in a city environment [8]. Among recent studies, rapidly urbanizing areas are changing the selective pressures of animal populations around them [9]. Plants also change in response to the presence and abundance of pollinators in a certain area [10]. If availability of parks and wildlife is scarce, the next best options are gardens in outdoor settings, which can still boost activity levels and wellness for humans [11].

Outdoor plants attract positive attention and can increase property values; particularly, in urban areas with dense populations and construction sites [12]. City designers and organizers may avoid incorporating a high density of trees in an urban environment due to potential risks related to branches falling or high maintenance, especially, if trees are closer to the road or electrical poles [13]. However, complete removal of trees and other plants from cities can have negative effects on human health [14]. The lack of green landscape can cascade along with other problems, such as financial or health struggles, which can all influence stress levels in humans [12]. Individuals immersed in a green environment may feel less stressed than those living in a completely urban landscape [15]. Nonetheless, preferences for urban environments may still be common in individuals that grew up in these areas. From a commissioner's standpoint, there are different ways to receive the benefits of nature without sacrificing roads and economic space. The strategic placement of plants in urban communities may induce relaxation via induction of the parasympathetic nervous system, while decreasing sympathetic nervous system activity associated to stress-induced responses [2].

Plants in the workplace are known to boost creativity and cognitive function, which in turn can increase productivity, and subconsciously, influence daily decisions as fundamental as where people would want to shop [16, 17]. Findings generally show that stores with a more "biophilic" design yield greater satisfactory ratings by consumers [18]. Similarly, the tree canopy area around one's home is significantly correlated to self-reported perceived general health [19]. Regarding work spaces, a study by Mangone et al. [17] found that natural areas were highly preferred to traditional, indoor work areas among employees doing research work at a university in Netherlands. However, when being outdoors is not possible, simple additions of potted plants or having windows with views of parks or other green spaces have been shown to reduce the negative effects of being indoors for long periods of time [14]. These studies showed that incorporating green spaces into outdoor and indoor workplaces may have a positive influence in the employees' overall sense of wellbeing. Positive effects of nature on humans are induced by different sensory signals. A nice view, bird songs, water sounds, the scent of plants and flowers can stimulate relaxation [20]. Even though a full immersion in nature (with all senses) would be preferable to artificial or partial exposures to a natural environment, the latter alternatives can still provide health benefits [21]. For example, videos and images of natural environments are known to ease a stressed state [22]. Additionally, auditory, and/or olfactory stimuli have been shown to provide benefits comparable to visual stimuli from nature [20]. Likewise, nature sounds may provide similar effects to those of music on humans. Previous studies have revealed that music can lessen the impact of stressful events [23], and relieve depression and other psychological conditions [24]. These auditory-induced responses may have a wide range of variability, as bias of musical preference could skew results from subject to subject [25]. The benefit of certain sounds, such as natural running water, may even be more beneficial than listening to soft music, and could be linked to human evolution in natural environments [26]. In a society where urbanization is expanding, maximizing the integration of urban and natural areas can have profound implications for mental health [27]. Current knowledge suggests that negative effects of daily stressors, in the absence of direct access to nature, may be alleviated by simply listening to recordings of nature sounds, and/or watching videos that engage both auditory and visual stimuli.

Noise pollution is a common and unavoidable factor in metropolitan areas. Noises from traffic, sirens, construction sites, and other city sources are known to induce stress in human populations [28]. A previous study has shown that individuals exposed to the sound of traffic walk significantly faster than those taking an alternate route of equal distance with the presence of trees and birdsongs [28]. Likewise, after laboratory simulation of urban auditory stimuli, nature sounds were found to quickly help individuals to relax [29]. In addition, nature sounds played before a stressful experience; like surgery, can significantly reduce patient anxiety levels [30]. A recent study has showed that nature sounds can significantly reduce physiological stress after just seven minutes of exposure [4]. These previous studies showed the importance of incorporating nature in urbanized environments to improve human health. However, access to natural environments can be limited for some human populations [6]. For these individuals, partial or artificial exposure to nature through audio or video of nature sounds and images could be a potential way to gain some of the benefits that nature may provide on health and cognition [31].

The main goal of the research presented here was to evaluate the effects of different types of sounds (i.e., nature and man-made sounds) on physiological and psychological responses of female college students. Given the challenges that arose with the COVID-19 pandemic, the original research plans had to be modified to be completed remotely. Specifically, we evaluated the effect of (i) a mixture of nature sounds including water sounds and birdsongs, and (ii) a mixture of urban sounds including heavy traffic and sirens using videoconference WebEx meetings as trials. While it can be predicted that a mixture of nature sounds can be perceived as more relaxing than a mixture of urban sounds, it can be expected there could be a range of variability due to individual preferences or differences in the perception of the distinct sounds from subject to subject. Additionally, acute lethargic, anxiety, and/or depressive-like symptoms have been reported in some individuals as a result of the coronavirus epidemic [32]. This research study will provide important information regarding how different environments (i.e., nature versus urban environments) may affect physiological and psychological responses of human subjects, which could be related to stress or relaxation. This information could be further applied to boosting cognitive performance [31], and improving general wellbeing [26]. Additionally, this study was amongst the first conducted during the start of the COVID-19 pandemic, which used a virtual approach to address an important research topic that could be used to ameliorate stress responses during challenging times, e.g., the pandemic quarantine, isolation and subsequent acclimation to work from home environments.

2. Materials and Methods

The Bowling Green State University Institutional Review Board provided expedited review and approved the protocol for this study (project ID: 1502803-3; April 25, 2020).

2.1 Participants

2.1.1 Inclusion Criteria

The research population for this study included twenty female university students from 18 to 28 years of age. Only females were recruited in this study due to the difficulty in recruiting volunteer participants, especially, during the start of the global COVID-19 pandemic, and to mitigate potential variation due to previously reported gender differences in physiological responses [33]. There were no other exclusion criteria in this study.

2.1.2 Recruitment

Recruitment included approved text for emails and university announcements, in addition to information provided through BGSU online classes via Canvas course shells. Along with the recruitment text, each participant received a copy of the IRB stamped consent form for a full description of minimal risk, confidentiality, and the voluntary nature of the study. If the contacted individuals expressed interest, they selected a meeting time on any weekday from 6 to 8 pm. Upon confirmation of a time for a WebEx meeting, each participant was emailed the files they would need for the study. These files included the sound mixes, a consent form as a Word document that each participant could sign, and a template to insert physiological and psychological measurements taken by the participant during the study. In addition, the researcher directly guided the students through each recorded activity via WebEx teleconference meetings.

2.2 Experimental Sounds

All sounds used were specifically collated for this study. Six Individual sound segments were acquired through “Freesound.org.” Three sound segments were used for each mix of nature and urban sounds. Nature sounds consisted of birdsong and running stream water, while urban sounds included traffic, construction, and sirens. Five out of the six sounds were obtained under the “Creative Commons 0,” without copyright license, as the creators included them on freesound.org as public domain for free and open use. The last sound was obtained under the attribution category of “Creative Commons Use.” Under this license, credit is given to sound creator, Klankbeeld (https://freesound.org/people/klankbeeld/) for the production of one of the sounds used in the urban sound mix for this study. The sound file was not altered and a link to the attribution and license is required and included herein (https://creativecommons.org/licenses/by/3.0/).

Each of the six sounds were normalized using the free software, Praat, to equalize them to the same average volume of 70 dB. Then, these normalized files were assembled using the standard version of sound software Ableton Live 10 using a MacBook Pro Model A1502 (Apple, Cupertino, CA, USA). Using the sound software, overall volume was slightly modified, each segment was repeated to fill seven minutes, and the collection of each of the segments was grouped to be exported as an mp3 file to be sent to the participants. With the restriction of file size capabilities in an email, mp3 files were used instead of wav files. Each sound segment was set to 7 minutes following methods by Largo-Wright et al. [4], since they found this time of exposure to be effective to significantly reduce physiological stress in a similar setting (after a “brief nature sound intervention”). Both the urban and nature sound files were identically exported; therefore, they had the same average and peak dB values. This ensured that each participant would hear each of the sound mixes at the same volume.

2.3 Experimental Design

2.3.1 Participant Correspondence

This study was completed during the COVID-19 pandemic; therefore, all contact with the participants was virtual, including classroom recruitment through Canvas course shells, email communication, and videoconference meetings via WebEx. Each participant was only asked to participate in a single, one-hour meeting that was used for instruction, listening to the sounds, and self-recording of their heart rate and breathing rate, as well as completing the Positive and Negative Affects Schedule (PANAS) survey [34] before and after listening to the nature and city sounds. In addition, two questions related to perception of the two environments (perceived comfort) were answered by participants before the sound trials.

Twenty-four hours before each trial, the experimenter emailed the participant asking them to follow their regular individual, daily routine, including their normal amount of sleep and caffeine consumption. Additionally, participants were asked to avoid eating foods with excessive amounts of carbohydrates (compared to their regular diets). An initial questionnaire was completed after the consent form to ensure there have been no abnormal changes in diet, rest, or physical activity that could alter physiological or psychological measurements.

2.3.2 Participant Trials

A within-subject approach was used to evaluate the effects of nature and man-made city sounds on physiological and psychological measurements in human subjects. Each participant listened to both the mixture of nature sounds and the mixture of city sounds. For counterbalancing, the order was randomly assigned using a random integer generator within a TI-Nspire CX CAS (Texas Instruments, Dallas, TX, USA). In each trial, there was a 10-minute period between listening to each set of sounds to allow for the participants' vital signs to return to baseline.

The dependent variables were recorded at the beginning of the study (as a baseline), and immediately after each of the 7-minute sound segments. Heart rate was recorded by the carotid pulse. The researcher instructed subjects to manually record their heart rate by placing their middle and index fingers to the side of their windpipe for 15-seconds. Time was kept by the experimenter, giving signals to start and stop counting. Similarly, each participant was asked to count the number of breaths they took in 60-seconds. For this purpose, participants were asked to count the number of times that they inhaled (i.e., every time the chest/abdomen rose). When both physiological vitals were successfully recorded, each participant completed the PANAS survey.

The PANAS included 20 affect states that the participants had to rate depending on how they were feeling at that moment, using a 5-point Likert Scale ranging from 1 (very slightly or not at all) to 5 (extremely). The ten positive affect (PA) and the ten negative affect (NA) states are included in Table 1. Total scores for the PA and NA were estimated separately by adding the individual responses (Likert 1-5) for all items within each affect category (ranging from 10 to 50). Higher PA and NA scores represented higher self-reported affect in each category [35]. Consistency and reliability of these scores have been previously reported [34]. In addition, before the sound trials started, the participants answered two questions related to perception of the two types of sounds using a Likert scale of 1-7 (1 = very stressful and 7 = very relaxing).

Table 1 Mean score and standard error (SE) for each individual emotion included in the positive and negative affect schedule (PANAS) using a Likert scale of 1 – 5, with a score of 1 signifying "very slightly or not at all" and a score of 5 signifying "extremely".

PANAS Emotion/Feeling	Baseline		After City Sounds		After Nature Sounds	
	Mean	***SE***	***Mean***	***SE***	***Mean***	***SE***
Positive Affect Emotions						
Interested	3.80	0.22	2.80	0.24	3.15	0.27
Excited	2.95	0.13	2.20	0.24	2.40	0.05
Strong	2.55	0.22	1.85	0.22	2.40	0.23
Enthusiastic	3.15	0.00	2.10	0.18	2.70	0.00
Proud	2.55	0.21	1.90	0.21	2.30	0.29
Alert	3.30	0.07	3.05	0.07	2.60	0.00
Inspired	2.40	0.10	1.55	0.15	2.75	0.00
Determined	2.55	0.00	1.90	0.15	2.20	0.00
Attentive	3.40	0.26	2.95	0.25	3.00	0.26
Active	2.35	0.29	1.90	0.22	1.75	0.23
Negative Affect Emotions						
Distressed	1.35	0.05	2.30	0.19	1.05	0.10
Upset	1.00	0.23	1.50	0.23	1.00	0.27
Guilty	1.10	0.07	1.10	0.07	1.00	0.00
Scared	1.25	0.22	1.40	0.20	1.00	0.30
Hostile	1.00	0.26	1.60	0.32	1.00	0.16
Irritable	1.05	0.30	2.00	0.14	1.10	0.28
Ashamed	1.10	0.18	1.10	0.23	1.00	0.16
Nervous	1.95	0.24	2.00	0.23	1.25	0.13
Jittery	1.80	0.24	2.40	0.18	1.35	0.16
Afraid	1.10	0.07	1.25	0.12	1.05	0.05

2.3.3 Sound Normalization for Each Participant

To achieve a comfortable volume for the sounds that were played, a free online loudness meter, created by Youlean, was used. Each subject was asked to use headphones to mitigate auditory distraction from their surrounding environment. Prior to listening to the sounds, participants were asked to open the nature (or city) sounds file and adjust their volume to achieve an average volume of approximately 70 dB. The participants were then asked to keep their volume constant for the rest of the study to keep average volumes constant between both sets of sounds.

An average of 70 dB was chosen as it resembles a conversational-level volume, which is safe from any potential noise-induced hearing loss [36]. Peak volumes in both mixes did not pass 87 dB. At 100 dB, sounds could cause potential damage after 8 hours of continuous exposure [37, 38]; therefore, participants were exposed to sounds that were in a completely safe range throughout the study. While listening to each of the sound segments, participants were asked to keep their eyes open, remain in a seated and neutral position, and to concentrate on the sounds to the best of their ability.

2.4 Statistical Analysis

The data generated from this research project was statistically analyzed using SAS Software version 9.4 (SAS Institute, Cary, NC, USA). Repeated measures Analyses of Variance (rmANOVAs) were conducted to test for the effects of the sound treatments (i.e., nature and city sounds) and subjects on vital signs, and PANAS scores (baseline and after sounds measures). When assumptions of normality and heterogeneity of variance were not met or for PANAS scores, data were rank-transformed. Pairwise comparisons among treatment means were performed using Fisher's Least Significant Difference tests when ANOVA models were significant (protected LSD). In addition, a measure of perceived comfort with city and nature sounds before the sound trials was analyzed using a Kruskal-Wallis test.

3. Results

Results from this study provide evidence that participants differentially responded to nature and city sounds both at the psychological and physiological levels. The rmANOVAs showed no significant effects of the sound treatments on heart rate ($F_{2, 38}$ = 2.99; P = 0.0625), but significant effects between subjects ($F_{19, 38}$ = 25.59; P < 0.001) denoting a large variability in this measure among participants (Table 2 and Figure 1a). There were, however, statistically significant effects of treatments and subjects on respiration rate (Treatment: $F_{2, 38}$ = 12.87; P < 0.0001; and Subject: $F_{19, 38}$ = 6.06; P < 0.0001; Table 2). Multiple comparisons among treatment means showed that respiration rates after listening to nature sounds were significantly lower (by 23%) from those after the city sound intervention. Baseline measurements were not statistically different than either of the two sound interventions (Figure 1b). Psychological measures of positive and negative affect schedule (PANAS) scores differed after city and nature sounds. The PANAS scores included positive affect scores (PAS) and negative affect scores (NAS) (Table 1). The sound treatments had a statistically significant effect on total PAS ($F_{2, 38}$ = 15.72; P < 0.0001) and NAS ($F_{2, 38}$ = 24.84; P < 0.0001), and the effect of subjects was also significant for PAS ($F_{19, 38}$ = 9.12; P < 0.0001), but not for NAS (Table 2). Multiple comparisons among treatment means showed that listening to city sounds induced a 23.4% decrease in the mean total PAS of the participants compared to their baseline scores (Figure 2a). However, mean PAS after nature sound intervention was not significantly different from either of the other two groups. For total NAS, there was a statistically significant effect of sound treatment ($F_{2, 38}$ = 24.84; P < 0.0001), and no significant results for subjects ($F_{19,38}$= 1.73; P = 0.0752). Pairwise comparisons revealed that mean total NAS after city and after nature sounds were significantly different from each other and from baseline scores. Mean total NAS of participants increased by 31.1% (from baseline) after listening to the city sounds, while listening to the nature sounds yielded a 14.9% decrease in negative affect scores (Figure 2b). The measure of "perceived comfort" with the two types of environments prior to the sound trials was also significantly different ($F_{1, 19}$ = 52.22; P < 0.0001). As shown in Figure 3, the average Likert scale perception of city sounds before the start of the sound trials was 2.85 while the average perception of nature sounds was 6.25 indicating that nature sounds were perceived as more "comforting" than city sounds.

Table 2 Analyses of variance evaluating the effects of sound treatments (city and nature sounds), and subjects (in a within-subject design) on vital signs, and rank-transformed positive and negative affect scores (PAS and NAS, respectively). Asterisks denote a statistically significant P-value (P < 0.0001).

Source	**Treatments**		**Subjects**	
	DF	F-value	DF	F-value
Heart Rate	2, 38	2.99	19, 38	25.59*
Respiration Rate	2, 38	12.87*	19, 38	6.06*
Positive Affect Score	2, 38	15.72*	19, 38	9.12*
Negative Affect Score	2, 38	24.84*	19, 38	1.73

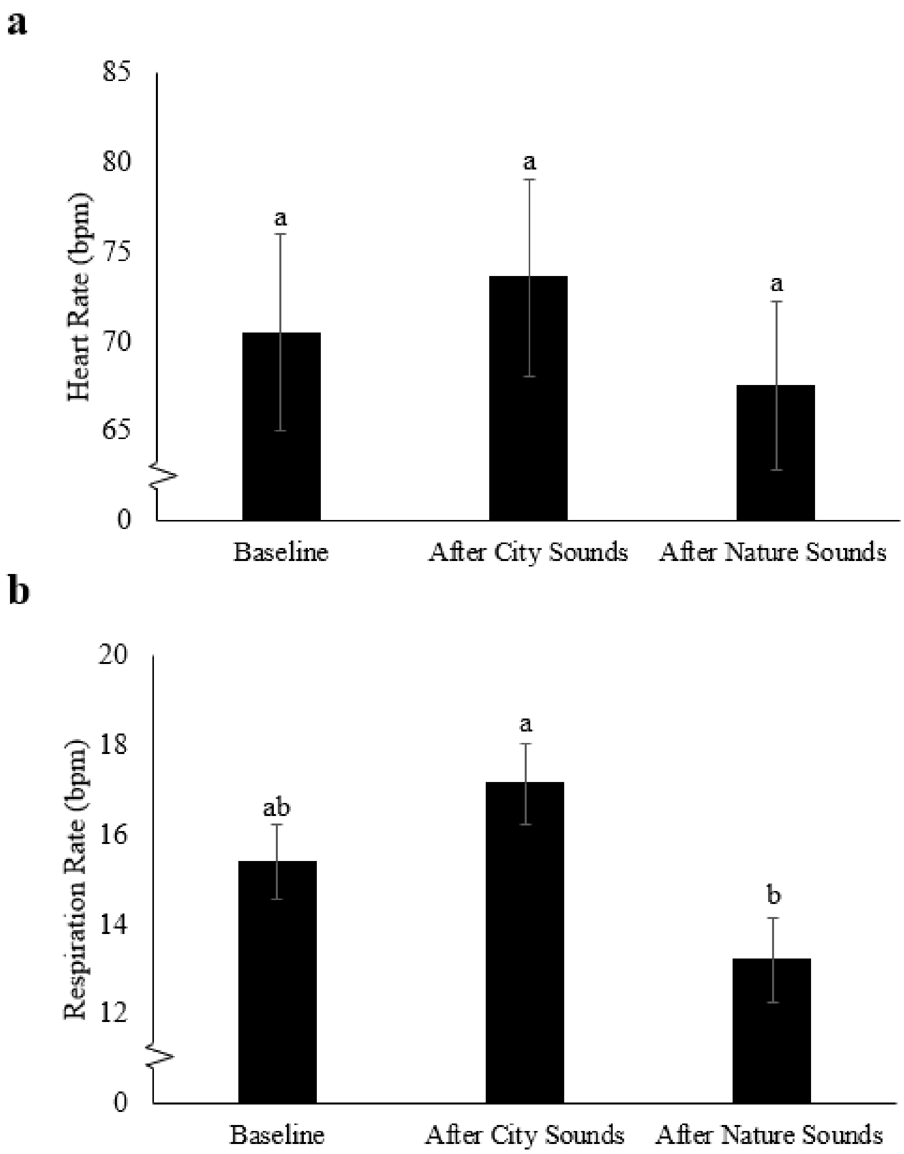

Figure 1 Effects of individual, 7-minute city and nature sound interventions on means and standard errors of the following vital signs: (a) manually recorded heart rate, and (b) respiration rate. Different letters denote a statistically significant difference among means of the physiological variables (P < 0.05).

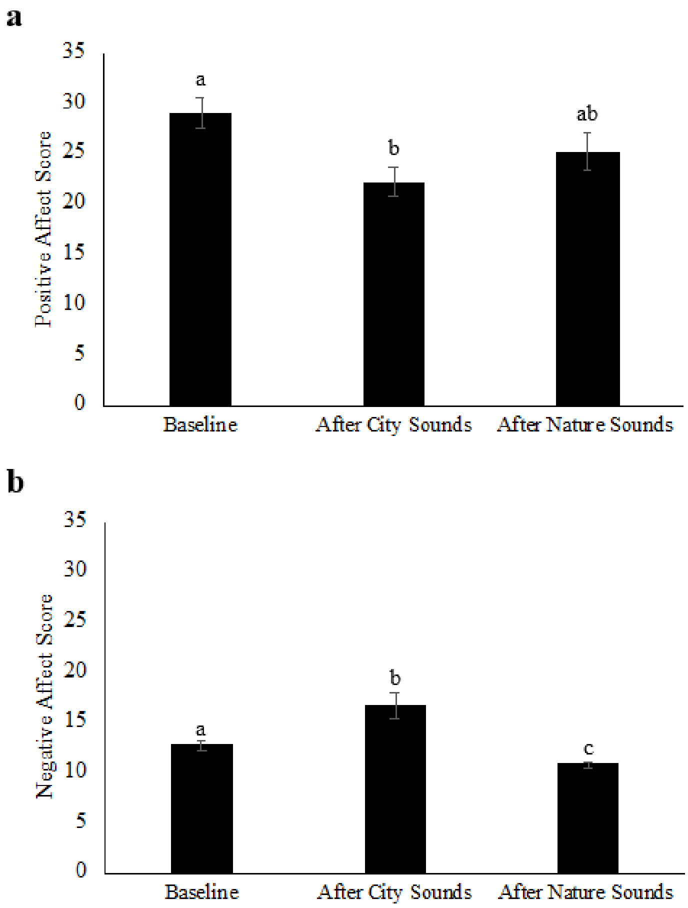

Figure 2 Effects of individual, 7-minute city and nature sound interventions on the Positive and Negative Affect Schedule (PANAS) questionnaire scores. Means and standard errors for (a) Positive Affect Scores (PAS), and (b) Negative Affect Scores (NAS). Different letters denote a statistically significant difference among means of the scores ($P < 0.05$).

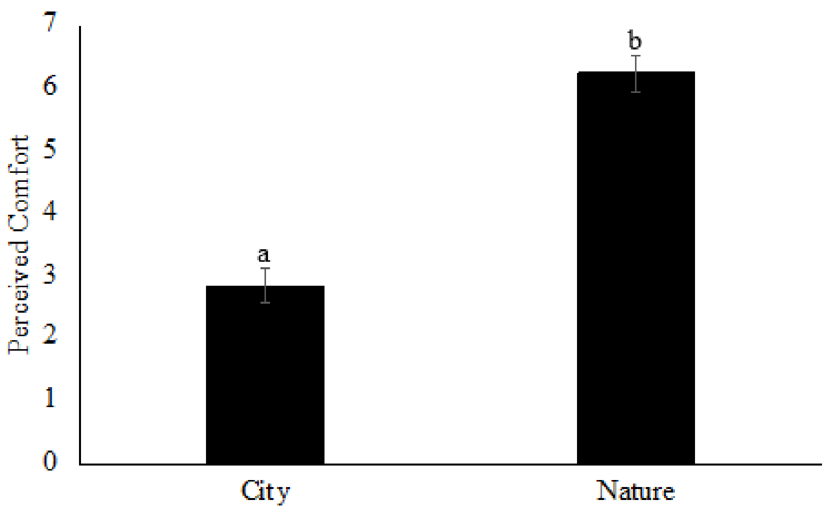

Figure 3 Means of perceived comfort with city sounds and nature sounds using a Likert scale of 1-7 (1 = very stressful to 7 = very relaxing). Different letters denote a statistically significant difference between the means of the scores ($P < 0.05$).

4. Discussion

Previous studies have evaluated the effects of human physiological and psychological responses to the environment [14, 20, 39]. Most of these studies explored the effects of urban and natural environments in a fully immersive way, in which the environments stimulate several senses simultaneously (e.g., sight, sound, and smell). The present study focuses on auditory stimuli, and these findings are the first to explore how humans react to urban and natural auditory stimuli using a remote setting from a home rather than a laboratory or natural setting. Results showed that listening to pre-recorded nature sounds induced a significantly lower respiration rate and Negative Affect Score (NAS) than city sounds. This outcome was in accordance with a survey completed before the sound interventions, in which participants showed a higher (statistically significant) preference for nature over city environments. These results suggest that humans still have a positive, innate connection to nature, even using a virtual modality.

Overall, the experimental results showed that the sounds of an urban area can have different effects on human psychology and physiology than the sounds of a natural environment. From the two physiological variables measured (i.e., heart rate and respiration rate), heart rate was the only variable in this study that was not significantly influenced by the different sound interventions. A previous study by Gee et al. [40] also showed a lack of significant changes in heart rate, but an improvement with anxiety and mood when participants observed aquariums with live fish, plants, and water in a laboratory setting. The lack of significant results in heart rate in this study could be primarily due to a large variability in this vital sign across participants (significant within-subject effects on heart rate). Individual measurements ranged from a minimum of 56 bpm to a maximum of 136 bpm. In addition to inter-person variability, heart rate naturally changes very rapidly, and although it was measured immediately after each sound intervention, there was a delay for some of the participants to quickly find their carotid pulse.

Regarding the other physiological variable measured in this study, a lower respiration rate after listening to nature sounds (compared to after city sounds) suggested activation of the parasympathetic nervous system (PNS). The PNS is a major part of the autonomic nervous system (ANS) that, when activated, is responsible for a relaxation state. This occurs through increased vagal activity, as the vagus nerve is a major conduit between the lungs and the brain [41, 42]. In contrast, higher respiration rate after listening to city sounds may be associated to activation of the sympathetic nervous system (SNS), which is the major part of the ANS that is induced by stressful situations. Activation of the PNS alleviates negative effects of stressors by reducing SNS activity; and thus, balancing ANS responses. Studies by Fuertes et al. [43] and Kondo et al. [44] showed that participants exposed to green spaces had lower respiration rates and fewer chronic health conditions compared to participants living in urban environments. Our findings suggest that individuals from urban areas that don't have easy access to parks may benefit from listening to pre-recorded nature sounds to help activate their PNS and induce a relaxation response.

As part of the peripheral nervous system, PNS and SNS also influence psychological states, as happy or relaxed moods are congruent to PNS activity. Contrarily, anxiety and depressive feelings can be associated with SNS activation mediating stress responses. In this study, psychological states were measured using the Positive and Negative Affect Schedule (PANAS), which includes a list of emotions associated to positive and negative affect scores (PAS and NAS, respectively). The statistically significant decrease in PAS and increase in NAS after the city sound intervention suggest that urban sounds may trigger stress responses that decrease positive emotions and enhance negative affect responses. This could result in a negative effect on work ethic, compassion, and purpose in an urban environment [15, 45]. In contrast, the significant decrease in NAS after the nature sound intervention indicated that these sounds can ameliorate negative emotions. This result is in accordance with a study by Berman et al. [46], in which the PANAS questionnaire was also used to evaluate whether natural settings may improve the mood of participants. These researchers also found that NAS scores were higher in urban environments and lower in participants exposed to natural environments. Higher NAS scores suggest that humans may have a more negative, stressed mood when living in an urban setting. In our study, the NAS of participants after the seven minutes of nature sound exposure scored a 10.8 ± 0.32. This result is close to the minimum possible for NAS, as PANAS scores range from ten to fifty. Low NAS scores after the nature sound intervention suggest that listening to a pre-recorded set of natural sounds in any situation may help mitigate the effects of negative emotions, by engaging the PNS; and thus, balancing the autonomic nervous system.

In addition, this study assessed innate preferences of participants for urban or nature environments before the sound interventions. There was a statistically significant difference between perception of the two environments, with a higher preference for nature sounds (i.e., all but two participants chose a six or seven on a Likert scale of one to seven). This result is in agreement with similar studies in which natural environments were preferred to urban areas and indoor workspaces [17, 27, 47]. The preference for nature may derive from prior experience as well as evolutionary history [48, 49]. Humans may have an innate connection to natural environments, as our ancestors evolved in direct contact with nature and gathered in small groups. However, the effect of experience, whether children are raised in an urban or rural community, may influence subsequent preferences later in life [50]. Results from this study suggest that humans may still perceive natural environments as more relaxing and linked to less negative emotions.

Due to the Covid-19 pandemic, this study was completed remotely. Although participants had the benefit of completing the sound trials in the comfort of their own homes, there were a few difficulties related to working remotely. Communication with each participant was done via email and through the WebEx videoconference call during a one-hour long trial. Additionally, each participant used their own device and headphones to play sounds. Given that participants used their own devices, there was variation among headphone and speaker types/brands, which likely contributed to differences in the quality of the sounds. Additionally, even though we used the Youlean loudness meter to control for potential differences across operating systems and computer brands, there was likely some variation in volume levels that could not be accounted for. To maximize volume control, the participants were asked to modify the volume of their devices to a level they would consider to be a comfortable, normal conversational volume. Although this volume might not have been exactly 70 dB, the goal was that every participant would at least perceive the volume as “conversational”, which should have been close to 70 dB. The reliance on each participant to record their own physiological vital signs, i.e., respiration and heart rates, was likely subjected to random error and was a limitation of this virtual research study. However, with the aid of the experimenter guiding students through these tasks and keeping the time for the measurements throughout the live virtual session, these random effects should have been minimized. Generally, it is also important to note a potential bias in terms of sound perception that humans may experience. Associations with sounds may be linked to different cultural perceptions across the world [51];

however, this bias was assumed to be minimal due to participants sharing the same native language and culture.

Despite the limitations associated with performing virtual research at the start of the global COVID-19 pandemic (April - August, 2020), this study demonstrated that a simple approach, such as listening to pre-recorded nature sounds, could help decrease stress-related responses and associated negative emotions of female college students. There is the potential of finding accessible tools that could improve general feelings of well-being during challenging times, and help people with feelings of anxiety and/or depression. The COVID-19 pandemic also promoted people to spend more time in nature to cope with the isolation and decreased social interactions [52]. It is also known that exposure to nature and volatile organic compounds (VOCs) emitted by plants and trees can boost our immune systems [53]. For those populations that don't have easy access to natural spaces, our findings could be used to explore whether recordings of sounds from natural environments may bring some relief by engaging PNS activity and deactivating the SNS associated to stress responses [6]. However, humans may have different preferences for a single, dominant sense, and nature sounds may not be relaxing for everyone [54, 55]. Given differences among individual preferences and dominant senses, further studies would help to elucidate if virtual experiences with nature could somehow reproduce some benefits related to actual exposure to a natural setting. In any case, a full immersion in nature, as happens during a walk in the woods, may override a single dominant sense, and help to reconnect with our roots in nature.

5. Conclusions

The results from our study showed that a seven-minute segment of nature sounds can be used to improve well-being through decreasing self-reported respiration rate and abating negative affect states in female college students. Additionally, a survey revealed that participants had a higher preference for nature than for urban environments.

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Author Contributions

Both authors designed this experiment and worked together to write this manuscript. DJD met with participants to record the raw data and MGB performed the statistical analyses.

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Competing Interests

The authors have declared that no competing interests exist.

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