



Article

Listening to Forests: Comparing the Perceived Restorative Characteristics of Natural Soundscapes before and after the COVID-19 Pandemic

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Abstract: Natural sounds are known to contribute to health and well-being. However, few studies have investigated what makes a natural sound renew and re-energize people, especially in the face of significant stressors caused by the Corona Virus Disease 2019 (COVID-19). This study examined the interactive mechanism towards the perceived restorative characteristics of natural soundscapes: fascination, being-away, compatibility, and extent. Two groups of data were collected in Burleigh Heads National Park, Australia, before the outbreak of COVID-19 ($n = 526$) and in October 2020 ($n = 371$). The objective measures of L_{Aeq} confirmed that the acoustic environment of Burleigh Heads National Park are quiet and peaceful for attention restoration. The results of the subject evaluation revealed that participants from the post-COVID-19 group reported higher stress levels, while there was a greater mental restoration through water sounds. There are significant differences between the pre- and post-COVID-19 groups with respect to the relationships among the perceived restorative characteristics of natural soundscapes. The direct effects of extent and fascination, as well as the mediating effects of fascination, were more significant among the post-COVID-19 group than the pre-COVID-19 group. However, the effects of being-away on compatibility were less significant in the post-COVID-19 group. This study reduces the gap that exists on the research of environment–people–health–wellbeing nexus. Knowledge about natural soundscapes encourages administrations to consider it as a guideline for the planning and management of natural resources, especially during the COVID-19 pandemic.

Keywords: natural soundscape; mental restoration; health and well-being; sustainability; COVID-19



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1. Introduction

Uncertainties due to the Corona Virus Disease 2019 (COVID-19), which has killed at least 1,189,295 people and infected 45,812,181 as of the end of October 2020, have seriously disturbed lives worldwide. There is wide consensus that the COVID-19 pandemic not only affects physical health, but also mental health and well-being [1,2]. The pandemic will end, but its negative effects on mental health and the well-being of the public will remain for a long time. In the coming months and years, the number of people who will need psychiatric help is going to increase, requiring a global reconsideration on how to improve the public's mental health [3].

According to the Attention Restoration Theory (ART) developed by Kaplan, mental restoration can be defined as the renewal of “adaptive resources” depleted in ongoing efforts to meet the demands of everyday life [4]. There is evidence suggesting that the natural environment is perceived to have better restorative properties than artificial urban settings [5–8]. Sounds are an essential part of the natural environment, and emerging

research has demonstrated that natural sounds might have potential benefits for health and well-being [9,10]. For example, even though the visibility of avifauna may be limited to forests, their songs and calls are almost universally able to enhance a person's mood and help a person relax [11]. Humans relate to their sonic environments on an emotional level by interpreting the sensory information they give, which gives rise to the concept of the soundscape: "the sonic environment as perceived and understood, by people, in context" [12]. Interest in natural soundscapes as a therapeutic resource has ancient foundations [13].

A growing body of empirical studies has indicated that listening to different types of natural soundscapes provides psychological restoration to both adults and children [14]. Payne evaluated the perceived restorative potential of soundscapes in different environments [15]. The results showed that the natural soundscapes in rural areas were perceived as the most restorative, while the artificial soundscapes in urban cities were the least. Similarly, Qiu et al. recruited 563 tourists to rate their reactions to the soundscapes of various waterfalls in Jiuzhai Valley National Park, China, and found that this kind of soundscape directly triggers pleasant memories and allows tourists to relax and recover, both cognitively and physiologically [16]. Ratcliffe et al. pointed out that birdsong is one of the most prominent sounds experienced in a restorative environment [17]. Through a semantic analysis, Yuan Zhang found that the restorative effect of hearing birdsong was the strongest of those in urban green spaces, followed by the sound of running water and background music [18].

In accordance with the ART, Payne developed a Perceived Restorativeness Soundscape Scale (PRSS) to describe the four characteristics that are important for soundscapes to produce a restorative effect [15]. These are fascination, being-away, compatibility, and extent. Fascination allows people to rely on effortless attention instead of directed attention. Being-away refers to a physical or psychological shift away from everyday soundscapes. Extent is the coherence, scope, and richness of a sonic environment that enables the individual to feel as if he or she has explorative potential. Compatibility refers to the fit between the individual's need and the sonic environment. Soundscapes vary in the level of each characteristic, thus altering the overall restorative quality of each environment [19]. A natural soundscape that promotes mental health can be defined as a restorative soundscape [20,21].

Some studies have started to consider causal relationships between the perceived characteristics of restoration, but most of them have focused on the total environment or only the perceived restorativeness of a visual stimulus [22]. Laumann stated that the four characteristics of perceived restoration are in different hierarchies [23]. Fascination and extent represent the characteristics of the environment, while being-away and compatibility describe the perception of a person. In a further study, Herzog et al. measured the inner-relation of the four characteristics in 70 urban and natural settings [7]. They found that correlations across these characteristics generally followed the predictions of Laumann, while they appeared most notably in the relationship between extent and compatibility. A fascinating environment draws people's attention effortlessly, freeing them from a situation that induces fatigue, and people define the meaning of an environment with their intrinsic motivations [24]. Extent has been considered a key antecedent of fascination as it provides a sufficiently rich and coherent environment to constitute a whole world for exploring fascination [25]. The perception of being-away is induced by various fascinating attractions and is most likely to be experienced in a larger environment in which elements follow each other in a relatively sensible, predictable, and orderly manner [26]. In turn, being-away can change the mindset, making people aware of the compatibility between self and the sonic environment [27]. Letho expanded being-away into "mentally away" and "physically away," and found that these two factors explain a very large percentage of the variance of compatibility (37%) [28].

However, based on our current knowledge, previous studies lack attention to the perceived restorative characteristics of natural soundscapes. They tend to take types of natural soundscapes in forests as the "treatment" without further dissecting the restorative

process of natural soundscapes [29]. As Galinsky puts it, a very important, but much neglected question is “What makes a natural soundscape renew and re-energize people?” [30]. According to above studies towards the perceived restorative characteristics, we hypothesize that there are potential correlations among the perceived restorative characteristics of natural soundscapes. More specifically, we posited that fascination of natural soundscapes would mediate the relationship between extent and being-away as well as extent and compatibility. Additionally, we hypothesized that the being-away of natural soundscapes plays a mediating role between extent and compatibility as well as between fascination and compatibility.

The perceived restorative characteristics of natural soundscapes have been associated with a number of variables (e.g., preference, diversity, complexity, and affect) [31]. Specifically, a higher level of stress has significant effects on the restorative process of natural soundscapes [32]. For example, high-stress visitors in a national forest park are more sensitive to natural soundscapes, thus making the pathway from the perceived restorative characteristics to mental health more significant, which in turn promotes greater improvement in their quality of life [33]. A study during a previous viral outbreak found that among patients who survived the Severe Acute Respiratory Syndrome (SARS) epidemic, natural soundscapes may have differentiated restorative effects depending on the level of stress [34]. The outbreak of COVID-19 has created relatively new forms of stressors for mental health [35]. Recent research proved that stress raised during the COVID-19 pandemic could recovery from simpler virtual exposure to forest environments with combined audio and visual stimuli. It provides a benchmark to disentangle the determinants of health effects due to real natural soundscapes in forests [36].

However, empirical research regarding the actual restorative process of natural soundscapes during the COVID-19 pandemic is rather limited, and the process needs to be investigated. For instance, is the restorative process of natural soundscape after the outbreak of COVID-19 different from that before? Which restorative characteristics of a natural soundscape most effectively allow mental recuperation during the COVID-19 pandemic? How do the four constructs of the PRSS interact with each other to recovery mental fatigue caused by the fear of COVID-19? There is still no universally accepted model to capture the psychological mechanism of natural soundscapes in restoring mental health during the global pandemic. Therefore, we assumed the perceived stress level as a moderating factor and, thus, the perceived restorative characteristics of natural soundscapes may have different interactive mechanisms due to the COVID-19 pandemic.

With respect to the potentially negative psychological consequences associated with the outbreak, this study aimed to investigate how the perceived restorative characteristics of natural soundscapes interact with each other, especially during the COVID-19 pandemic. The selection of pre-COVID-19 and post-COVID-19 samples allowed us to investigate whether comparable effects were observed in different contexts and confirm the stability and specificity of the relationship among fascination, being-away, extent, and compatibility [37]. Figure 1 shows a conceptual diagram of the hypothesized relationships in a moderated mediation model. Knowledge about how the perceived restorative characteristics of natural soundscapes aid in improving mental health is essential due to the increased level of anxiety and stress that has been reported in association with the outbreak of COVID-19.

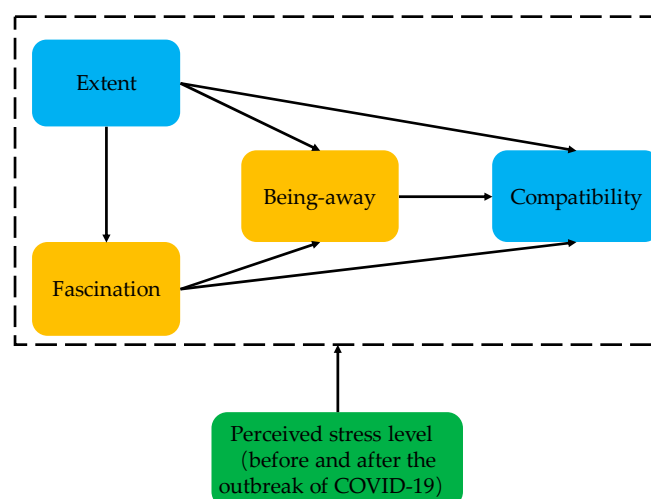


Figure 1. A conceptual model of hypothesized relationships. Note: the yellow rectangles represent mediating variables, while the green rectangle represents moderating variables.

We developed the following hypotheses:

Hypothesis 1 (H1). *There are correlations among the restorative characteristics of natural soundscapes.*

Hypothesis 1a (H1a). *The extent of natural soundscapes directly affects perceived fascination.*

Hypothesis 1b (H1b). *The extent of natural soundscapes directly affects the perception of being-away.*

Hypothesis 1c (H1c). *The extent of natural soundscapes directly affects perceived compatibility.*

Hypothesis 1d (H1d). *The fascination of natural soundscapes directly affects the perception of being-away.*

Hypothesis 1e (H1e). *The fascination of natural soundscapes directly affects perceived compatibility.*

Hypothesis 1f (H1f). *The being-away of natural soundscapes directly affects perceived compatibility.*

Hypothesis 2 (H2). *The fascination of natural soundscapes is a mediator in the model.*

Hypothesis 2a (H2a). *The fascination of natural soundscapes mediates the relationship between extent and being-away.*

Hypothesis 2b (H2b). *The fascination of natural soundscapes mediates the relationship between extent and compatibility.*

Hypothesis 3 (H3). *The being-away of natural soundscapes is a mediator in the model.*

Hypothesis 3a (H3a). *The being-away of natural soundscapes mediates the relationship between extent and compatibility.*

Hypothesis 3b (H3b). *The being-away of natural soundscapes mediates the relationship between fascination and compatibility.*

Hypothesis 4 (H4). *Perceived stress level moderates the relationship between the restorative characteristics of natural soundscapes.*

2. Materials and Methods

2.1. Study Site and Soundscape Description

The Burleigh Heads National Park in Australia, rich in natural soundscapes, offered one of the best locations for conducting the current study. The park is the first and only national forest park to combine urban life, ocean cultural heritage, and forest resources in Australia. It covers an area of 3008.8 hectares, and is located in eastern Gold Coast, Queensland (Figure 2). The forest accounts for 60% of the park's area, creating various natural soundscapes. Moreover, there are 696 types of vascular plants, 867 species of insects, and 181 species of birds in the park, all of which provide a special environment with various natural soundscapes. The largest music sharing platform in Australia, *Australian Music Online*, launched a sound album named "The natural sounds of Burleigh Heads" in 2018. The album was so popular that 50 million people downloaded it in its first month. This made natural soundscapes in the Burleigh Heads Beach National Park one of the best well-known attractions of the park.

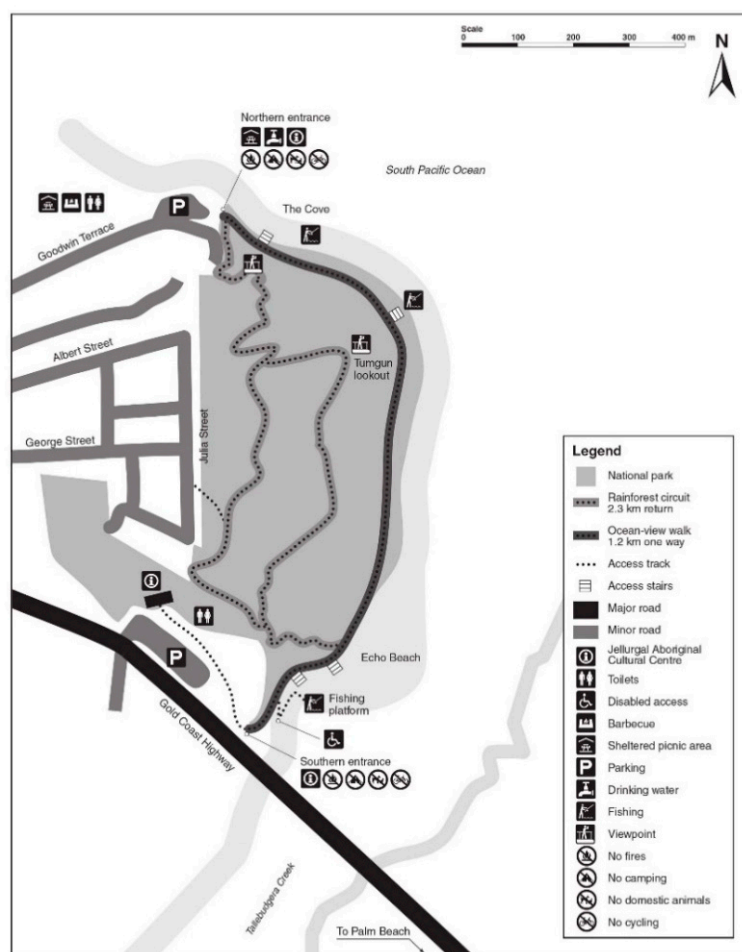


Figure 2. Map of Burleigh Heads National Park in Gold Coast, Australia.

The most favorite activities carried out in Burleigh Heads National park are hiking, relaxation, social event, and eco-tourism, which are closely associated with mental restoration (Figure 3). Since the weather is pleasant all the year round, there are little variations on natural soundscapes of the study site. According to the popular sound album, the natural soundscapes most perceived by visitors includes various birdsongs, ringing voice of rivulets, sounds of waterfalls, sounds of wind, faraway sounds of surf, raindrops,

sounds of insects, rolls of thunder, animal barking, etc. Interestingly, after the outbreak of COVID-19, the natural soundscapes in the park have increased. For example, the sea eagles reappeared to soar along the coast and visitors heard their sounds at Tumgun Lookout.



Figure 3. Burleigh Heads National Park.

2.2. Objective Evaluation of Sound Level

The objective evaluation of sound level aims to explore whether the acoustic environment of the study site is proper for mental restoration. Sound level are extremely variable over time, making it difficult to assess. The continuous equivalent sound pressure level (L_{Aeq}) has been defined by many authors as a constant sound level whose acoustic energy value is equal to the average energy of the sound level fluctuation over a total measurement time interval. According to ISO 12913-2:2018, an evaluating procedure was designed to measure global L_{Aeq} , the maximum A-weighted level L_{AMax} , and the minimum A-weighted level L_{AMin} [38]. The evaluation of sound level were taken on the trails of Burleigh Heads National Park where corresponded to the sites frequented by visitors. All the evaluations were conducted on spring daytime (10:00 a.m.–5:00 p.m.) when the weather facilitated enjoyment of natural soundscapes and analyzed, and when the spaces were most visited by people. The sound level meter was placed close to the location of participants' ears at 1.2–1.5 m above the ground. The measurement had the duration of 180 s during the participants filled in the questionnaire, which allowed a simultaneous assessment of the acoustic environment and soundscape perception on site. The soundscape level was calculated according to the following equations:

$$L_{Aeq} = 10 \log \left[\frac{1}{T} \left(\int_0^T 10^{L(t)_{pA}/10} dt \right) \right]$$

where, $L(t)_{pA}$ is the A-weighted sound-pressure level at time t (1 s) and T is the time interval (180 s) considered.

2.3. Participants and Procedures

All participants gave their informed consent for inclusion before participating in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Council of the City of Gold Coast (reference number COMACT-8027311). Data collected from existing visitors who were taking an actual vacation effectively avoided the limitations observed in most previous studies that utilized a convenient student sample in a laboratory setting with recordings or videos simulating various environmental settings [39]. The first questionnaire was distributed at the Burleigh Heads National Park from 21–25 October, 2019, during the park's peak season. A total of 600 domestic visitors were randomly selected. Excluding incomplete surveys, 526 valid questionnaires were collected for data analysis.

Owing to the severity of the COVID-19 pandemic, stringent control measures were enforced in the Burleigh Heads National Park since the beginning of 2020, and the park did not open all of its attractions until September 2020. Therefore, we conducted the second on-site survey from 5–7 October, 2020, which is a public holiday for the Queen’s Birthday. A total of 500 domestic visitors were randomly selected in the park, and 371 valid questionnaires were collected.

As shown in Table 1, of the 526 participants who visited the Burleigh Heads National Park before the outbreak, 54.94% were female. The average age of the participants was 38.42 years (standard deviation (SD) = 8.48), ranging from 20 to 70 years. The majority of the participants had a diploma or higher degree (67.30%). Of the group that visited the park in the post-COVID-19 period, 56.33% were female. The average age of the participants was 36.21 years (SD = 6.52). Most of them had a diploma or higher degree (78.17%). The analysis showed no significant differences in demographic characteristics between the pre-COVID-19 group and the post-COVID-19 group, making these two sets of data suitable for multi-group analysis to compare the effects of natural soundscapes in different periods.

Table 1. Profile of respondents.

Characteristics	Frequency		Percentage (%)	
	Pre-COVID-19 ¹ Group	Post-COVID-19 ¹ Group	Pre-COVID-19 ¹ Group	Post-COVID-19 ¹ Group
Gender				
Male	237	122	45.06	43.67
Female	289	249	54.94	56.33
Year of birth				
1990–1999	98	74	18.61	19.95
1980–1989	142	106	27.03	28.57
1970–1979	105	71	20.01	19.14
1960–1969	83	43	14.75	11.59
1950–1959	68	39	11.94	10.51
Before 1950	40	38	7.66	10.24
Level of education				
No formal education	22	7	4.18	1.89
Primary school	45	26	8.56	7.01
Secondary school	84	41	15.97	11.05
Diploma and above	354	290	67.30	78.17
Other	21	7	3.99	1.89

¹ Covid-19 means the Corona Virus Disease 2019.

2.4. Measurements

2.4.1. Perceived Stress Level

To measure participants’ mental states before and after the COVID-19 outbreak, the Perceived Stress Scale-10 items (PSS-10) developed by Mitchell was employed [40]. The PSS-10 consists of ten items and captures the main characteristics of people’s stress levels. The Australian version of the PSS-10, delineated by the World Health Organization (WHO), has shown fairly good reliability and validity in previous empirical research across different contexts. Participants rated the frequency from 1 (“never”) to 5 (“very often”) with which they had encountered stressful situations in the past month before visiting the Burleigh Heads National Park (e.g., “How often have you been upset because of something that happened unexpectedly?” and “How often have you felt you were unable to control the important things in your life?”). Cronbach’s alpha was 0.87 in pre-COVID-19 samples and 0.79 in post-COVID-19 samples.

2.4.2. Perceived Restorative Characteristics of Natural Soundscapes

The perceived restorative characteristics of natural soundscapes were the main variables and were measured using the PRSS. This self-reported scale was originated by Payne to assess perceptions of a soundscape’s potential to provide psychological restoration [15]. As reported by Payne, the PRSS successfully differentiates between soundscapes from

different types of environments, the same type of environment, and within the same place. However, several items displayed the same meaning and may have confused participants. For example, the items “I find these sounds appealing” and “My attention is drawn to the sounds here” were highly correlated. Through a pilot test with a convenience sample of 100 university students, we revised the scale to fit the survey context and changed “sounds” to “natural soundscapes” in the items. Therefore, a 16-item scale was developed to measure the perceived restorativeness of natural soundscapes in four dimensions: fascination (e.g., “I find these natural sounds are appealing”), being-away (e.g., “These natural sounds are different to what I usually hear”), extent (e.g., “The extent of these natural sounds seems limitless to allow exploration”), and compatibility (e.g., “Hearing these natural sounds hinders what I would want to do in this place”). Each subscale consists of four items, using a five-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree). Cronbach’s alpha was 0.74 in pre-COVID-19 samples and 0.71 in post-COVID-19 samples.

2.5. Analytical Strategies

Descriptive statistics (means, standardized deviations, correlations) and internal consistencies were analyzed using SPSS 25.0. Subsequently, this study adopted partial least squares structural equation modeling (PLS-SEM) to test the predictive power of the conceptual model. To confirm the perceived destination restorative qualities, Chen et al. used an approach based on the concept of covariance, which is covariance-based SEM (CB-SEM) [38]. PLS-SEM is another frequently applied multivariate analysis method to estimate a structural equation model by empirical data. PLS-SEM explains the residual variance of the latent variables, therefore, its goal is to predict rather than confirm the key constructs. It has more advantageous when trying to explore theory than CB-SEM [41–43]. As this study focuses on the evaluation of a set of predictive relationships among the perceived restorative components of natural soundscapes, the use of PLS-SEM seems warranted in the model examination. Moreover, since the post-COVID-19 group contained only 371 participants, PLS-SEM was particular suitable for analyzing such small sample rather than CB-SEM [42]. A PLS-SEM sampling rule of thumb is the “ten times rule”, and previous studies have identified a sampling threshold for PLS-SEM in the order of 100 samples [44,45]. In both cases, we can safely conclude that 526 and 371 are acceptable sample sizes for the two groups examined in this study.

3. Results

3.1. Characteristics of Sound Level

Since technical visits and observations of Burleigh Heads National Park and its surroundings indicated that the flow of sound sources in the measured time remained stabilized, we decided to take the arithmetic mean value of acoustic data in each research period as characterization of sound level. The standard deviations in Table 2 indicated that all of the acoustic data are close to the average, representing a steady state of acoustic environment in each research period. The average of L_{Aeq} before the outbreak of COVID-19 is 45.9 dBA while the average of L_{Aeq} during the COVID-19 pandemic is 41.3 dBA. The highest maximum level was recorded at pre-COVID-19 period (52.6 dBA L_{AMax}), which is slightly above the threshold for forest parks (50 dBA) by Australian standard of Acoustic Community Noise (AS 1055:2018). The lowest minimum level was recorded during the COVID-19 pandemic (40.1 dBA L_{AMin}). The mean value of L_{Aeq} , L_{AMax} , and L_{AMin} at the post-COVID period are lower than their counterparts from before the COVID-19 outbreak.

Table 2. Descriptive analysis.

Construct/Items	Pre-COVID-19 Period		Post-COVID-19 Period	
	Mean value	Standard deviation	Mean value	Standard deviation
Equivalent continuous sound level L_{Aeq} (dB)	49.5	2.21	41.3	3.83
Maximum A-weighted level L_{AMax} (dB)	52.6	3.67	47.9	2.85
Minimum A-weighted level L_{AMin} (dB)	46.2	2.03	40.1	1.98
Fascination (FA)				
FA1. I find these natural sounds are appealing	4.07	0.81	4.56	0.72
FA2. My attention is drawn to the interesting natural sounds here	4.11	0.77	4.60	0.77
FA3. These natural sounds make me wonder about things	4.09	0.79	4.48	0.78
FA4. I am engrossed by these natural sounds	3.96	0.81	4.25	0.85
Being-away (EA)				
EA1. These natural sounds are different to what I usually hear	4.12	0.75	4.08	1.06
EA2. Listening to these natural sounds gives me a break from my day-to-day listening experience	4.11	0.77	3.85	1.12
EA3. These natural sounds are refuge from unwanted distractions	4.17	0.76	3.98	0.98
EA4. I feel free from work, routine and responsibilities when I am with these natural sounds	4.08	0.79	3.95	1.06
Extent (EX)				
EX1. All the natural sounds I'm hearing belong here (with the place shown)	3.27	0.98	4.54	0.91
EX2. All the natural sounds I'm hearing are clearly organized	3.16	0.95	4.28	0.87
EX3. The natural sounds I am hearing fit together to form a coherent sonic environment	3.21	1.14	4.39	1.04
EX4. The extent of these natural sounds seems limitless to allow exploration	3.19	1.14	4.20	1.06
Compatibility (CP)				
CP1. These natural sounds relate to activities I like to do	3.74	0.95	4.02	1.32
CP2. These natural sounds fit with my personal preferences	3.79	0.82	4.17	1.22
CP3. I rapidly get used to hearing these natural sounds	3.62	0.92	4.24	1.31
CP4. Hearing these natural sounds hinders what I would want to do in this place	3.81	0.85	3.99	1.01
Perceived stress Scale (PSS)				
PSS1. How often have you been upset because of something that happened unexpectedly?	3.81	0.77	4.41	0.78
PSS2. How often have you felt you were unable to control the important things in your life?	3.92	0.87	4.47	0.96
PSS3. How often have you felt nervous and stressed?	3.94	0.86	4.45	0.86
PSS4. How often have you felt confident about your ability to handle your personal problems?	3.79	0.95	3.82	1.02
PSS5. How often have you felt that things were going your way?	3.56	0.95	3.83	1.12
PSS6. How often have you found you could not cope with all the things that you had to do?	3.46	0.82	3.86	0.81
PSS7. How often have you been able to control irritations in your life?	3.56	0.94	4.11	0.79
PSS8. How often have you felt that you were on top of things?	3.25	1.14	4.19	0.78
PSS9. How often have you been angered because of things that were outside of your control?	3.58	1.24	4.20	0.96
PSS10. How often have you felt difficulties piling up so high that you couldn't overcome them?	3.61	1.11	3.80	1.03

3.2. Descriptive Analysis of Each Constructs

As indicated in Table 2, the mean values of all variables from both the pre-COVID-19 and post-COVID-19 group are higher than 3.50. Being-away had the highest mean value of perceived restorative characteristics for participants in the pre-COVID-19 group, followed by fascination, compatibility, and extent. For the post-COVID-19 group, fascination had the highest mean value, followed by extent, compatibility, and being-away. Participants from the pre-COVID-19 group reported lower stress levels during the last month before they visited the park than participants from the post-COVID-19 group. The mean values for the constructs of fascination, extent, and compatibility were higher among the post-COVID-19 group than pre-COVID-19 group.

3.3. Common Method Variance

Common method variance (CMV) can be a significant concern in self-administered surveys when the same participant responds to all questionnaire items. It is problematic if a single latent factor would account for the majority of the explained variance. This study applied Harman's single-factor test, as recommended by Podsakoff et al. to account for potential CMV [46]. Harman's test returned a multi-factor rather than a single-factor solution, and the first factor explained only 19.6% of the total variance. Since the first factor did not capture most of the variance, revealed that common method bias was not a severe issue and, thus, can be disregarded in this study.

3.4. Measurement Model

The measurement model used in this study included four constructs: fascination, being-away, extent, and compatibility. The loading of each indicator on its associated latent variable (LV) was higher than 0.75. Generally, the loading should be higher than 0.70 for indicator reliability to be considered acceptable [45]. Hence, the indicators in the measurement model reached a satisfactory indicator reliability level. The composite reliability (CR) coefficient was also used to assess construct reliability and should be higher than 0.70 to establish internal consistency [41]. For each group of data, Table 3 indicates that the CRs of all reflective LVs within the PLS path model were higher than 0.8, which is higher than the required threshold of 0.70. Thus, the measurement model possessed acceptable reliability. To establish convergent validity, the average variance extracted (AVE) of the LVs should be higher than 0.5 [47]. Table 3 shows that all of the AVE values for each group were higher than the critical threshold of 0.50, which supports the convergent validity of the measures.

Discriminant validity is the extent to which each LV is distinct from other constructs in the model [39]. In order to establish discriminant validity, the heterotrait-monotrait ratio has recently been established as a superior criterion compared to more traditional assessment methods, such as the Fornell–Larcker criterion [48]. Previous studies have suggested two different thresholds of 0.85 and 0.9 for the Heterotrait-Monotrait ratio of correlations (HTMT) criterion to establish discriminant validity [49]. The current study uses a more conservative level of 0.85 (i.e., HTMT.85) to assess discriminant validity. For each group-specific model estimation, discriminant validity was established since all results of the HTMT.85 criterion (Table 4) are below the critical value of 0.85. Together, these results lend sufficient confidence that the measurement model fits the data well, and all of the construct measures were reliable and valid.

Table 3. Individual item reliability and construct validity.

Constructs/Items	Loading		CR		AVE	
	Pre-COVID-19	Post-COVID-19	Pre-COVID-19	Post-COVID-19	Pre-COVID-19	Post-COVID-19
Fascination (FA)			0.84	0.92	0.58	0.74
FA1	0.76	0.86				
FA2	0.86	0.89				
FA3	0.83	0.88				
FA4	0.81	0.81				
Being-away (BA)			0.88	0.91	0.73	0.73
BA1	0.82	0.83				
BA2	0.85	0.89				
BA3	0.88	0.86				
BA4	0.86	0.84				
Extent (EX)			0.86	0.93	0.60	0.77
EX1	0.83	0.87				
EX2	0.83	0.90				
EX3	0.78	0.89				
EX4	0.76	0.86				
Compatibility (CP)			0.86	0.88	0.62	0.64
CP1	0.87	0.78				
CP2	0.88	0.75				
CP3	0.76	0.84				
CP4	0.83	0.83				

Table 4. Discriminate validity with Heterotrait-Monotrait ratio of correlations (HTMT).

Constructs	Fascination	Being-Away	Extent	Compatibility	Fascination	Being-Away	Extent	Compatibility
		Pre-COVID-19 group				Post-COVID-19 group		
Fascination								
Being-away	0.42				0.50			
Extent	0.48	0.68			0.62	0.58		
compatibility	0.34	0.66			0.41	0.11	0.33	

In order to perform an Multi-Group Analysis (MGA) to compare the path coefficients between the two groups, the acceptability of the measurement models and measurement invariance should be established [41]. Common factor models are among the most frequently used methods for assessing measurement invariance in SEM. However, PLS-SEM is a composite model with LV scores calculated based on a composite model algorithm. Henseler et al. suggested the measurement invariance of the composite (MICOM) method for PLS-SEM [42]. Thus, the current study uses the MICOM approach to assess measurement invariance. MICOM is a three-step process. It involves configural invariance assessment, the establishment of compositional invariance assessment, and an assessment of equal means and variances. As per the MICOM procedure, the study established partial measurement invariance of the two groups (Table 5), which is a requirement for comparing and interpreting the MGA's group-specific differences of PLS-SEM results. The results confirm the three types of invariance, which implies that measurement invariance holds. Therefore, an MGA is possible.

Table 5. Results of invariance measurement testing using permutation.

Constructs	Configure Invariance	Compositional Invariance		Partial Measurement Invariance Established	Equal Mean Variance		Equal Mean Value		Full Measurement Invariance Established
		c-Value (c = 1)	95% CIs		Differences	95% CIs	Differences	95% CIs	
Fascination	Yes	0.93	[0.90, 1.00]	Yes	−0.16	[−0.17, 0.17]	−0.005	[−0.25, 0.24]	Yes
Being-away	Yes	0.98	[0.98, 1.00]	Yes	−0.02	[−0.02, 0.03]	0.004	[−0.25, 0.26]	Yes
Extent	Yes	0.92	[0.91, 1.00]	Yes	−0.12	[−0.14, 0.15]	0.000	[−0.13, 0.13]	Yes
Compatibility	Yes	0.94	[0.94, 1.00]	Yes	−0.19	[−0.22, 0.02]	−0.002	[−0.13, 0.17]	Yes

3.5. Structural Model

Coefficient of determination (R^2) indicates the amount of variance explained by exogenous variables [50]. The model appears to have an appropriate predictive power, with R^2 exceeding the required amount of 0.10. Moreover, the cross-validated redundancy (Q^2) values of all the endogenous constructs were well above zero, indicating the predictive relevance of our model [51]. A bootstrapping procedure was used to evaluate the significance of the path coefficients [41]. The hypotheses are supported when zero is outside the bootstrapped 95% confidence intervals. Figure 4 shows the PLS results for all the samples, which indicate that extent significantly influences fascination ($\beta_{pre} = 0.47$, $\beta_{post} = 0.58$, $p < 0.001$), being-away ($\beta_{pre} = 0.43$, $\beta_{post} = 0.48$, $p < 0.001$), and compatibility ($\beta_{pre} = 0.60$, $\beta_{post} = 0.83$, $p < 0.001$); fascination has direct effects on being-away ($\beta_{pre} = 0.45$, $\beta_{post} = 0.54$, $p < 0.001$) and compatibility ($\beta_{pre} = 0.61$, $\beta_{post} = 0.88$, $p < 0.001$); and being-away significantly influences compatibility ($\beta_{pre} = 0.69$, $\beta_{post} = 0.40$, $p < 0.001$). Thus, H1a, H1b, H1c, H1d, H1e, and H1f are all supported in both groups.

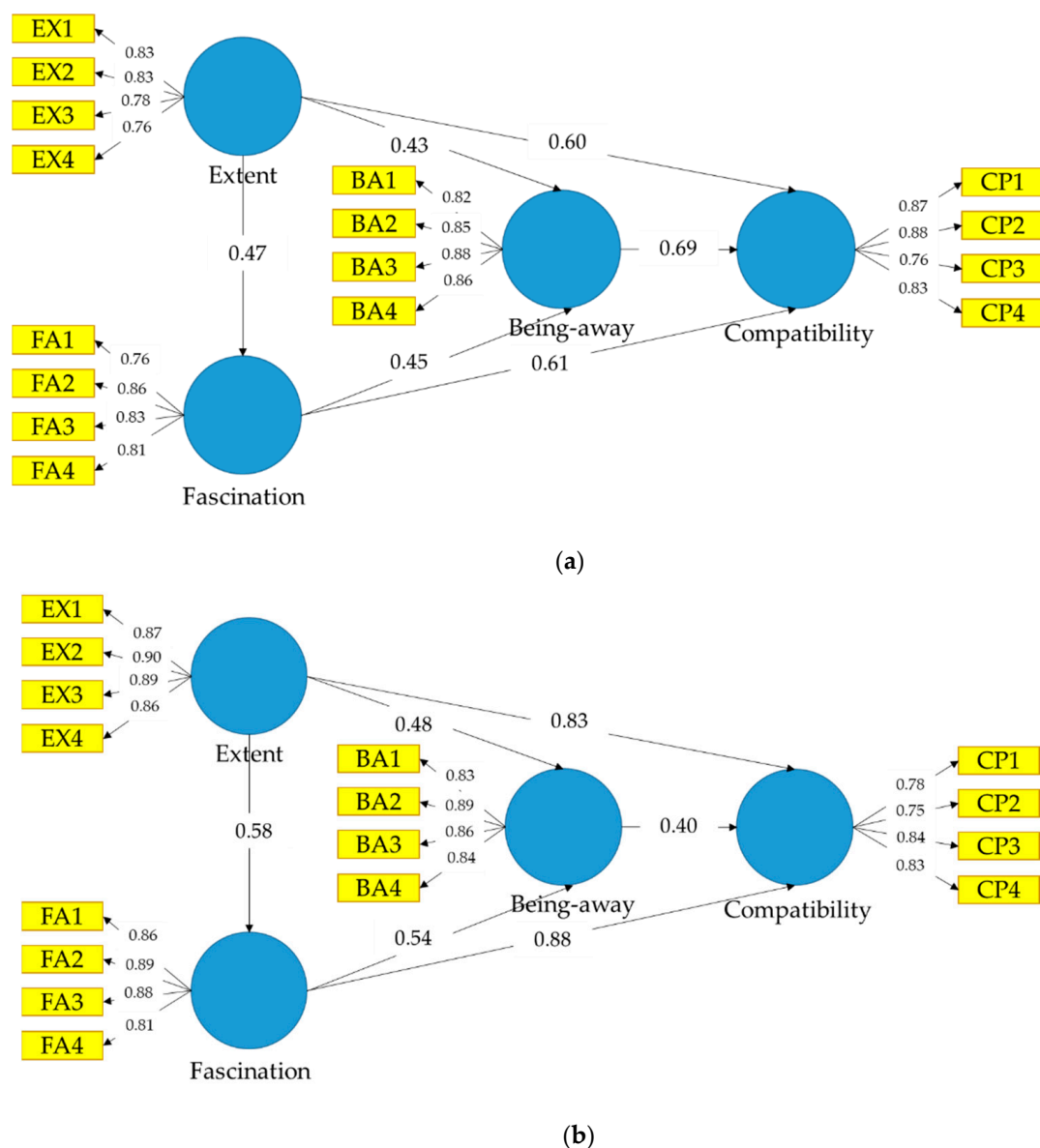


Figure 4. The examination of structural model: (a) the results of the structural model in the pre-COVID-19 group; (b) the results of the structural model in the post-COVID-19 group.

A bootstrapping approach was considered the most appropriate method to assess the mediating effect of fascination and being-away [52]. To establish the mediating effect, the indirect effects must be significant. In this regard, we applied the z statistic, which is significant at $p < 0.05$. If the z value exceeds 1.96 ($p < 0.05$), there is a mediating effect. To estimate the size of the indirect effect, we used the variance accounted for (VAF) value, which represents the ratio of the indirect effect on the total effect. The VAF can have a value from less than 20% (no mediation) to above 80% (full mediation). A situation in which the VAF is larger than 20% and less than 80% can be characterized as partial mediation [39].

As shown in Table 6, the study concludes that for the pre-COVID-19 group and the post-COVID-19 group, fascination partially mediated the relationship between extent and being ($\text{VAF}_{\text{pre}} = 32.81\%$, $\text{VAF}_{\text{post}} = 39.24\%$) as well as the relationship between extent and compatibility ($\text{VAF}_{\text{pre}} = 32.58\%$, $\text{VAF}_{\text{post}} = 38.06\%$). However, being-away played a partial mediating role between extent and compatibility ($\text{VAF}_{\text{pre}} = 33.33\%$, $\text{VAF}_{\text{post}} = 18.63\%$) as well as between fascination and compatibility ($\text{VAF}_{\text{pre}} = 33.70\%$, $\text{VAF}_{\text{post}} = 19.09\%$) only in the pre-COVID-19 group. The mediating effects of being-away from extent and fascination to compatibility were not significant. Therefore, H2a and H2b are supported in both groups whereas H3a and H3b are only supported in the pre-COVID-19 group.

Table 7 shows the MGA outcomes of two different nonparametric methods: Henseler's bootstrap-based MGA and the permutation test [47,48]. According to both of the methods, a p -value of differences between path coefficients lower than 0.05 or higher than 0.95 at the 5% level indicates significant differences between specific path coefficients across two groups [53]. There are significant differences between the pre-COVID-19 and post-COVID-19 groups in terms of the effects of extent on fascination ($\beta_{\text{pre}} = 0.47$, $\beta_{\text{post}} = 0.58$, $p = 0.03$ **) and compatibility ($\beta_{\text{pre}} = 0.60$, $\beta_{\text{post}} = 0.83$, $p = 0.00$ ***) as well as fascination on compatibility ($\beta_{\text{pre}} = 0.61$, $\beta_{\text{post}} = 0.88$, $p = 0.000$ ***). Notably, the effects of being-away on compatibility were much higher in the pre-COVID-19 group than in the post-COVID-19 group; it also shows a significant difference between the two groups ($\beta_{\text{pre}} = 0.69$, $\beta_{\text{post}} = 0.40$, $p = 0.00$ ***). However, the findings of this study do not support a significant difference between the two groups regarding the effects of extent on being-away ($\beta_{\text{pre}} = 0.43$, $\beta_{\text{post}} = 0.48$, $p = 0.11$) or of fascination on being-away ($\beta_{\text{pre}} = 0.45$, $\beta_{\text{post}} = 0.54$, $p = 0.10$). Both methods similarly confirm the significance or non-significance of the differences in the results, thus providing a multi-method confirmation of our findings.

Table 6. Examination of mediating effects.

	H2a		H2b		H3a		H3b	
	Extent -> Fascination -> Being Away		Extent -> Fascination -> Compatibility		Extent -> Being Away -> Compatibility		Fascination -> Being Away -> Compatibility	
	pre-COVID-19	post-COVID-19	pre-COVID-19	post-COVID-19	pre-COVID-19	post-COVID-19	pre-COVID-19	post-COVID-19
Indirect effects	0.21	0.31	0.29	0.51	0.30	0.19	0.31	0.21
Total effects	0.64	0.79	0.89	1.34	0.90	1.02	1.02	1.10
Sobel z test	7.28	6.25	11.24	9.95	18.53	0.86	9.74	1.13
Variance Accounted For (VAF)	32.81%	39.24%	32.58%	38.06%	33.33%	18.63%	33.70%	19.09%
Support	Partial mediation	Partial mediation	Partial mediation	Partial mediation	Partial mediation	No mediation	Partial mediation	No mediation

Table 7. Results of MGA.

Relationships	Path Coefficients Pre-COVID-19 ¹	Path Coefficients Post-COVID-19 ¹	CIs (Bias Corrected) Pre-COVID-19 ¹	CIs (Bias Corrected) Post-COVID-19 ¹	Path Coefficient Differences	p-Value Henseler's MGA	p-Value Permutation Test	Supported
extent -> fascination	0.47	0.58	[0.23, 0.57]	[0.35, 0.68]	0.11	0.03 **	0.02 **	H1a ✓
extent -> being away	0.43	0.48	[0.37, 0.71]	[0.32, 0.53]	0.05	0.11	0.26	H1b ×
extent -> compatibility	0.60	0.83	[0.45, 0.69]	[0.76, 0.87]	0.23	0.00 ***	0.00 ***	H1c ✓
fascination -> being away	0.45	0.54	[0.31, 0.51]	[0.52, 0.61]	0.09	0.10	0.17	H1d ×
fascination -> compatibility	0.61	0.88	[0.45, 0.70]	[0.67, 0.96]	0.27	0.00 ***	0.00 ***	H1e ✓
being away -> compatibility	0.69	0.40	[0.63, 0.86]	[0.37, 0.53]	−0.29	0.00 ***	0.00 ***	H1f ✓

¹ Note: ** $p < 0.05$, *** $p < 0.01$.

4. Discussion

This study bridged the gap in the restoration literature by conducting a comparative study before and after the outbreak of COVID-19 to develop and validate a conceptual model that captures the inner relationship among perceived restorative characteristics of natural soundscapes.

The statistical level of L_{Aeq} in Burleigh Heads National Park accords with Australian standard of Acoustic Community Noise (AS 1055:2018), indicating that the natural soundscapes in this site are quiet and peaceful for visitors to restore their mental fatigue [26]. It is noteworthy that the global soundscape level was 4 dB lower in the post-COVID-19 period (Table 2). This may be because the pandemic and related tourism containment measures have provided a tranquility space for reservation and recovery of natural soundscapes. Many of the artificial noises were eliminated. The acoustic environment of post-COVID-19 period with a higher presence of natural elements presented lower sound level and more diverse sound events, which tended to be positive for visitors' mental health [36].

The mean values of all variables from both the pre-COVID-19 and post-COVID-19 groups were higher than the threshold (Table 2). Together the component scores indicate the restorative effects of the natural soundscapes in Burleigh Heads National Park. This result provides a theoretical lens to show that natural soundscapes could be utilized to enhance public wellness.

Meanwhile, both of the structural models indicate support for the hypotheses that there are direct and indirect correlations among fascination, being-away, extent, and compatibility (Figure 4). The findings refute a previous argument by Kaplan, who found that all perceived restorative characteristics are considered to be at the same hierarchical level [4]. It is possible that extent and fascination are more related to the acoustic features of natural soundscapes, while being-away describes the individuals' perception of these natural soundscapes [54]. According to the conceptual model about environmental experience to study the soundscape, the place–activity–person nexus are closely related, with the interrelation being two-directional [55]. Therefore, the acoustic features of natural soundscapes have significant impacts on the psychological evaluation of the person-soundscape interaction [22]. Compatibility is influenced by the above three characteristics and explains the largest percentage of variance of restorative soundscapes [56]. Specifically, a natural soundscape's explorative potential (extent) and attention holding properties (fascination), enables individual to shift away from the previous situation to a novelty sonic environment (being-away), and in turn promotes a strong harmony between individual and natural soundscapes (compatibility), resulting in an opportunity for mental restoration.

The MGA revealed significant differences between the pre-COVID-19 and post-COVID-19 groups with respect to the interaction mechanism of the perceived restorative characteristics (Table 7). The effect of the extent on fascination and compatibility in the post-COVID-19 group was much larger than in the pre-COVID-19 group, thus supporting the argument that the perception of the natural soundscapes and the outcomes are highly dependent on the context and relevant contextual factors, not limited only to the acoustic features [57]. During the COVID-19 pandemic, the public is suffering from an increase in mental health problems, behavioral disturbances, and substance-use disorders [58]. The pre-measured stress levels of participants confirmed that post-COVID-19 samples were more stressed than their pre-COVID-19 counterparts before they visited the Burleigh Heads National Park (Table 2). The highly stressed groups were more sensitive to natural soundscapes, thus leading to exploration beyond what is immediately heard. Therefore, the pathways from extent to being-away and compatibility are more significant, and in turn promoted greater improvement in health and well-being. Therefore, the variation in effect size might be related to the stress level. This finding concurs with a previous conclusion that the higher the stress, the stronger the restorative effects of nature [59].

Moreover, the direct effects of fascination on compatibility and the mediation effects of fascination between extent and being-away as well as compatibility have increased significantly since the outbreak (Table 6). The aforementioned variances may be attributed

to the differences between soundscape and visualscape. The Burleigh Heads National Park is a partly closed space, which is more conducive for natural soundscapes preservation than other types of space [60]. Since the extent and diversity of natural soundscapes is more novel and interesting than ordinary visualscapes, individuals are more likely to focus on various natural soundscapes, restoring directed attentional fatigue [61]. A further explanation is that isolation measures made life tiresome and, thus, people are longing for a fascinate environment. The naturalness and diversity soundscapes in Burleigh Heads National Park after the outbreak of COVID-19 better meet the expectation of individuals than the unchanging visualscapes. Through the fascination of natural soundscapes, individuals can more freely and personally define the meaning of natural soundscapes in consonant with the goals of their experiencing, thus producing restoration.

In the current study, we found that the effect size of being-away on compatibility in the post-COVID-19 group was significantly lower than in the post-COVID-19 group ($\beta_{pre} = 0.69$, $\beta_{post} = 0.40$, $p < 0.001$). The mediation effects of being-away between extent and fascination, as well as between fascination and compatibility, were non-significant. Therefore, the perception of being-away in the post-COVID-19 group is less supportive of compatibility. This is quite different from the path coefficients through extent and fascination to compatibility. This is also inconsistent with the findings of previous studies on the restorative effects of visual stimuli [62]. Being-away involves a physical or conceptual departure from the present situation to a different environment [16]. However, in the current pandemic, the threat can be anywhere, even in the person next to us. Thus, people do not know how or where they can escape to [63]. In addition, stringent control measures—namely, quarantine, social distancing, and self-isolation—prevent people from leaving their homes. These measures can have a detrimental impact on mental health due to increased loneliness and reduced social interactions [64]. People become more dependent on their familiar environment and are reluctant to leave. As the large-scale of lifestyle change, the effects of being-away are weaker in restorative process due to conditions of the COVID-19 pandemic.

The findings of this study have several practical implications for health management. From a sustainability angle, managers and policymakers should take into account the importance of protecting natural soundscapes. Natural soundscapes have great potential to affect people's health and well-being, and contribute to the experience of green space as a wellness product. Listening to natural soundscapes does not require physical contact, which allows people to maintain a moderate social distance [65]. Therefore, the therapeutic effects of natural soundscapes are vital in the context of the current global health crisis. Over the years, sound has mainly been considered epidemiologically as “noise,” and most environment policies have focused on noise control and reduction. Unfortunately, reducing sound levels do not necessarily lead to improved quality of life. Natural soundscapes can be an effective antidote for overcoming mental health challenges. It is important to protect the sustainable development of various natural soundscapes to promote individuals' involvement in a pleasant environment.

Moreover, this research identifies the perceived restorative characteristics of natural soundscapes that can best foster efficient renewal of diminished functional resources and capabilities of individuals, especially facing the challenges inflicted by the global COVID-19 pandemic. Recovery from mental fatigue can be facilitated by the interaction of the perceived restorative characteristics of natural soundscapes. Since the effects of being-away have become weaker during the COVID-19 pandemic, short vacations within local surroundings that are rich in natural soundscapes should be recommended by policymakers. It is worth noting that, since the outbreak of COVID-19, it is important to seek natural soundscapes that are not too complex or disorganized. Disordered elements limit exploration and require attention to resolve confusion and, thus, are incompatible with the function of restoring individuals' mental fatigue. One strategy for managers and policymakers is to be mindful of the designs of natural soundscapes that help create harmony and captivating experiences [66].

Several limitations provide potential avenues for future research. This study is based on two groups of cross-sectional samples that have similar demographic characteristics to enable a comparative study. However, the results may not predict the restorative process of natural soundscapes after the COVID-19 situation is over. Longitudinal studies through the panel data would assist in investigating the impact of the perceived restorative capacity of natural soundscapes on mental health and well-being [67]. Moreover, this study only consider the average of L_{Aeq} and its corresponding maximum and minimum values in describing the acoustic environment. Perhaps Cartographic tools can be used in the future to present the energetic performance in different point of the park. Additionally, self-report measures were adopted because these allow for fast collection of data from individuals' direct responses towards natural soundscapes. The restorative outcomes often lack comparison with physiological and cognitive data from individuals, such as skin conductance, muscle tension, blood pressure, heart rate, brain waves, and so on [68]. Further research is needed to combine mixed methodologies to obtain more reliable results. Finally, this study only considers the perceived restorative characteristics of natural soundscapes. Future studies should be expanded to compare the restorative effects of soundscapes and visuals. Thereby, we would be able to capture individuals' restorative mechanisms and promote sustainable utilization of soundscape resources.

5. Conclusions

Overall, this study reduces the gap left by having no empirical studies that examine the perceived restorative characteristics of natural soundscapes in the face of the COVID-19 pandemic. The objective evaluation of the acoustic environment and psychological measures of the perceived restorative characteristics provide mixed support for the link between natural soundscapes and human well-being that has been reported previously. Findings unveiled four factors of natural soundscape, which are beneficial for mental restoration, namely extent, fascination, being-away and compatibility. The restorative process of natural soundscape imply a relationship among place–activity–person. The four characteristics are at different hierarchical levels and the relationships among them are bidirectional, the influence of one on the other may be positive to health and well-being. Together, the interaction of extent, fascination, being-away, and compatibility indicated the restorative benefits of natural soundscapes and can contribute to human health and sustainability.

The main conclusion that can be drawn from this study is that there are significant differences between pre- and post-COVID-19 groups with respect to the relationships among the perceived restorative characteristics of natural soundscapes. Through comparing pre-COVID-19 samples and post-COVID-19 samples in Burleigh Heads National Park, Australia, this study highlighted the strong and significant effects of extent and fascination on compatibility for individuals during the COVID-19 pandemic. It reveals that, rather than focusing on the visual stimulus from a traditional perspective, the extensive and fascinating soundscapes in natural environments also underpin the process of mental restoration, which is particularly important due to COVID-19. However, distinguished from previous studies, the perception of being-away in the post-COVID-19 group is less supportive of compatibility. Visitors' experience of isolation and expectation of safety after the outbreak of COVID-19 allow us take a new look at the restorative characteristics of natural soundscapes in improving the perception of forests.

This study adds to a growing body of evidence linking improvements in mental health to nature experiences. Additionally, our results add a novel field-based approach to understand what makes a natural soundscape in forests renew and re-energize people, especially in the face of significant stressors caused by COVID-19. As the pandemic of COVID-19 represents a massive global health crisis, the conclusion encourages managers and policymakers to consider the natural soundscapes as a wellness product in environmental administration.

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