2-2023

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Untangling the Additive and Multiplicative Relations between Natural Scenery Exposure and Human–Animal Interaction on Affective Well-Being: Evidence from Daily Diary Studies

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Abstract: Built nature spaces have been increasingly integrated into our urban environments in recent years with the aim of reaping their psychological benefits. However, despite numerous works of research on the relationship between nature exposure and well-being, most studies have looked into the benefits of well-being from the lens of isolated elements of nature, such as natural scenery or animal exposure. This study aims to fill in the gaps by examining the additive and multiplicative relationships between natural scenery exposure and human–animal interaction on affective well-being (i.e., positive affect, negative affect, and stress) through a daily diary study. Over seven days, natural scenery exposure, human–animal interactions, and affective well-being of 514 young adults were assessed. Through multilevel modelling, we found that natural scenery exposure was associated with increased positive affect at the within- and between-person levels. Moreover, human–animal interaction was associated with increased positive affect at the within-person level. No evidence was found for human–animal interaction as a moderator of the relationship between natural scenery exposure and affective well-being. Our findings support the additive, but not multiplicative, relations between natural scenery exposure and human–animal interactions on their influence on affective well-being. The exploratory analysis showed the lack of multiplicative relationship which can be attributed to the distinct mechanism of the effect between natural scenery exposure and human–animal interactions on affective well-being.

Keywords: nature; natural scenery; human–animal interaction; affective well-being; daily diary

Citation: Goh, A.Y.H.; Chia, S.M.; Majeed, N.M.; Chen, N.R.Y.; Hartanto, A. Untangling the Additive and Multiplicative Relations between Natural Scenery Exposure and Human–Animal Interaction on Affective Well-Being: Evidence from Daily Diary Studies. *Sustainability* **2023**, *15*, 2910. https://doi.org/10.3390/su15042910

Academic Editor: Grigorios L. Kyriakopoulos

Received: 31 December 2022
Revised: 31 January 2023
Accepted: 31 January 2023
Published: 6 February 2023

1. Introduction

The benefits of exposure to nature—the phenomena of the physical world collectively, including plants, animals, scenery, and other features and products of the earth, as opposed to humans or human creations—on human well-being have been widely studied over recent years [1,2]. Studies have reported that exposure to plants and natural scenery—such as spending time outdoors, especially in greenspaces (e.g., parks and nature reserves)—is associated with an improvement in mental well-being and positive affect [1,3,4], and a reduction in stress and negative affect [1,5,6]. For instance, a cross-sectional study showed that people who live in urban areas with more greenspaces reported higher positive affect and lower mental distress as compared to people who live in areas with less greenspaces [7]. Similarly, a recent daily diary study found that enjoying nature was associated with increased positive affect and reduced negative affect at the between-person level [8]. Driving in conditions with greater greenness is also found to be associated with improved mental status such as lower levels of tension, anxiety, and fatigue [9].

The well-being benefits of natural scenery are consistent with the Stress Reduction Theory, which addresses affective restoration from stress [10–12]. Stress Reduction Theory argues that natural environments invoke positive responses such as feeling relaxed and

calm [13,14]. This leads to an improvement in well-being and general reduction of psychological symptoms of stress, as viewing natural setting features has restorative qualities. Viewing natural features has restorative qualities as it improves the ability for paying attention and decreases mental fatigue. Moreover, unthreatening natural landscapes enable positive psychophysiological responses which increase positive affect and decrease arousal [14,15].

1.1. Human–Animal Interaction as Part of Nature

Although natural scenery is often the most focused-on element of nature, animals are another prominent natural element that is associated with human well-being. Research has shown that human–animal interaction—specifically human interactions with companion animals—trigger the release of oxytocin that supports improvements in human well-being [16–19]. Oxytocin is released based on the human's attachment to the animal during physical contact [18,20], and when the oxytocin system is stimulated upon interaction with animals, the hormone binds to several receptors which regulate emotions while increasing social behaviour [21]. Consistently, studies have shown that attachment to one's companion animal is a strong predictor of well-being [18,20,22]. For instance, several cross-sectional studies found that increased bonding with companion animals was correlated to an increase in self-compassion, sense of meaning and purpose, and the ability to cope with uncertainty [23–25].

Aside from companion animal exposure, several studies looking into animal encounters have also found psychological benefits from non-companion animal exposure. A systematic review of qualitative studies suggested that intentional interactions such as watching wildlife promote emotional well-being (e.g., improved mood) [26]. Viewing wildlife might also elicit feelings of awe, inspiration, and wonder, promoting psychological well-being, which leads to spiritual fulfilment [26]. Furthermore, a recent observational study found a significant improvement in stress hormone cortisol and mood levels after the participants' brief encounter with free-range lemurs in a walk-through enclosure [27].

Despite numerous works of research on the relationship between nature exposure and well-being, most studies have looked into the benefits of well-being from the lens of isolated elements of nature, such as natural scenery or animal exposure. However, in most natural environments, elements of nature such as natural scenery and animals tend to coexist in harmony [28]. Thus, the current study aims to investigate the unique contribution and the multiplicative contribution of two main elements of nature—natural scenery and animals—to individuals' well-being. Using data from a daily diary approach, we aim to make several methodological improvements from previous studies. First, the daily diary approach allows us to achieve high ecological validity by tracking our participants daily in a natural, rather than laboratory, setting [29–31]. Second, with repeated measures of exposure to natural scenery, human–animal interaction, and daily well-being over 7 days, the daily diary design allows us to estimate within-person associations involving our main variables and rules out any potential confounds that are stable over time [32,33]. Lastly, the repeated measure in daily diary also addresses issues related to memory distortion and increases the reliability of our participants' responses [32,34].

1.2. Current Study

Taken together, with methodological improvements using a daily diary design, the current study aims to examine the additive and multiplicative effect of exposure to natural scenery and human–animal interaction in improving affective well-being. Based on Stress Reduction Theory [35], we hypothesise that higher levels of natural scenery exposure would lead to improved affective well-being and less stress. We also hypothesise that human–animal interactions would additively lead to improved affective well-being and less stress over and beyond the contribution of natural scenery exposure. Lastly, we conducted an exploratory analysis to preliminarily investigate the possible multiplicative relationship between natural scenery exposure and human–animal interactions, such that the presence

of human–animal interactions would amplify the positive effect of natural scenery on well-being.

2. Materials and Methods

2.1. Sample

Data were drawn from two parts of a larger-scale project examining daily experiences from December 2020 to February 2021 [31,33,36,37], and from June 2021 to August 2021 [37]. It was conducted with a convenience sample of young adults in Singapore. From a total of 514 participants, 3500 observations of daily data were obtained (97.67% response rate). Baseline data were obtained through self-administered questionnaires, while data about participants' daily experiences were collected through seven days of self-administered online diary surveys. All data collection procedures were approved by the Institutional Review Board at a local university. All participants provided informed consent prior to data collection. A summary of descriptive statistics can be found in Table 1.

Table 1. Descriptive Statistics.

Variable	*M* or %	*SD*	Observed Range	Theoretical Range
Demographics				
Age (years)	22.24	1.68	19–30	
Sex (% female)	75.29%			
Ethnicity (% Chinese)	80.16%			
Monthly household income [a]	3.02	1.44	1–6	1–6
Subjective socioeconomic status [b]	6.16	1.32	2–10	1–10
Daily measures				
Natural scenery exposure	4.21	2.03	2–10	2–10
Human–animal interaction (% interacted)	15.29%			
Affective well-being				
Perceived stress	3.25	2.64	0–10	0–10
Negative affect	0.56	0.64	0–4	0–4
Positive affect	1.93	0.93	0–4	0–4

Note: $N_{participants}$ = 514, $N_{observations}$ = 3500. [a] Monthly household income was measured in Singapore Dollars on a 6-point scale (1 = Less than SGD 2000, 2 = SGD 2000–5999, 3 = SGD 6000–9999, 4 = SGD 10,000–14,999, 5 = SGD 15,000–19,999, 6 = more than SGD 20,000). [b] Subjective socioeconomic status was measured using the MacArthur scale [38]. Participants were presented with a 10-point ladder scale. Participants were told to place themselves on a rung indicative of "The ladder shown represents where people stand in their communities. At the top of the ladder are the people who are the best off, those who have the most money, most education, and best jobs. At the bottom are the people who are the worst off, those who have the least money, least education, worst jobs, or no job. Please place an 'X' on the rung that best represents where you think you stand on the ladder." (1 = lowest status, 10 = highest status).

2.2. Measures

Daily natural scenery exposure. Daily natural scenery exposure was assessed using the nature exposure scale [39], comprising two items (r_{within} = 0.71, $r_{between}$ = 0.89). The participants were told to include the elements of nature environments such as city parks in urban areas, plants and animals, natural geography, natural water courses, and waterscapes to standardise the elements which constitute natural scenery exposure. The first item captured the participant's level and rate of natural scenery exposure in their activities in their daily life (i.e., "In your everyday home, travel and work environments and activities, please rate your level of exposure to 'natural environments' today.") on a 5-point scale (1 = Very little of my everyday environment is natural, 3 = About half of my everyday environment is natural, 5 = Most of my everyday environment is natural). The second item captured the extent to which the participant took notice of nature in their environment (i.e., "How much did you notice these natural environments today?") on a different 5-point scale (1 = Not very much, 3 = Somewhat, 5 = A great deal). The scores were summed to form a minimum score of 2 and a maximum score of 10 for each day for each participant. Higher scores indicate a greater amount of natural scenery exposure.

Daily human–animal interactions. Two questions were asked each day to determine if the participants had positive and/or negative interactions with animals (i.e., "Did you have any enjoyable interactions with any animals today, including any pet(s)?", "Did you have any unenjoyable interactions with any animals today, including any pet(s)?"). Participants responded to each question using a binary response format (0 = No, 1 = Yes). The response of both positive and negative interactions with animals in a day were added together to form participants' daily human–animal interactions. The scores represented either a lack of human–animal interaction or a presence of human–animal interaction, with each category scoring 0 or more than 0, respectively.

Daily perceived stress. Perceived stress was measured using one item (i.e., "How stressed did you feel today?") through an 11-point slider (0 = no stress, 10 = extreme stress).

Daily negative and positive affect. Negative and positive affect were measured using the Daily Distress Scale from the Midlife Development Inventory [40]. Daily negative (α_{within} = 0.89, $\alpha_{between}$ = 0.96) and daily positive (α_{within} = 0.94, $\alpha_{between}$= 0.98) affect were independently measured through the aggregate of 14 and 13 items, respectively. The participants were instructed to report their emotions (e.g., "hopeless" for negative affect and "cheerful" for positive affect) experienced over the past 24 h on a 5-point scale (1 = none of the time, 5 = all of the time).

2.3. Analytic Plan

Through multilevel models, we examined (1) the direct association between natural scenery exposure and affective well-being, (2) the direct association between human–animal interaction and affective well-being, (3) the additive association between natural scenery exposure and human–animal interaction in relation to affective well-being, and (4) a moderation model whereby human–animal interaction moderated the relationship between natural scenery exposure and well-being. Well-being was operationalised as perceived stress, negative affect, and positive affect [41]. Three models were analysed for each well-being measure (i.e., negative affect, positive affect, and stress). As each study involved a seven-day diary survey, the measures for the variables were classified into level 1 (within-person) and level 2 (between-person).

We tested the first hypothesis that natural scenery exposure would be associated with increased well-being, the second hypothesis that human–animal interaction would be associated with increased well-being through the following models:

	Natural Scenery Exposure
Level 1	$(\text{Daily well-being})_{di} = B_{0i} + B_{1i}(\text{daily natural scenery exposure})_{di} + \varepsilon_{di}$
Level 2	$B_{0i} = \gamma_{00} + \gamma_{01}(\text{average natural scenery exposure})_i + \mu_{0i}$ $B_{1i} = \gamma_{10} + \mu_{1i}$
	Human–Animal Interaction
Level 1	$(\text{Daily well-being})_{di} = B_{0i} + B_{1i}(\text{daily human–animal interaction})_{di} + \varepsilon_{di}$
Level 2	$B_{0i} = \gamma_{00} + \gamma_{01}(\text{average human–animal interaction})_i + \mu_{0i}$ $B_{1i} = \gamma_{10} + \mu_{1i}$

In the Level 1 equation in the natural scenery exposure model, B_{0i} represents the intercept indicating individual i's average level of well-being on days without natural scenery exposure. B_{1i} represents the change in well-being from a day with low natural scenery exposure to a day with high natural scenery exposure, which signifies the reactivity in an individual's well-being to their level of daily natural scenery exposure. At Level 2, the intercept coefficient B_{0i} was modelled as a function of between-person differences, in terms of participant's average exposure over the seven days. The slope coefficient B_{1i} for each individual i was modelled as a function of average natural scenery exposure in order to test for slope variation of each individual by their natural scenery exposure. The deviation of the intercept and slope of each individual are shown as μ_{0i} and μ_{1i}. The

human–animal interaction model was identical to that of the natural scenery exposure model, with the exception that the predictors were changed from natural scenery exposure to human–animal interaction.

We tested the third hypothesis for the additive association between natural scenery exposure and human–animal interaction on affective well-being (Figure 1), where the results of Model 1 and 2 were utilised to examine if natural scenery exposure and human–animal interaction will contribute independently to well-being using the following model:

	Additive Model
Level 1	$(\text{Daily well-being})_{di} = B_{0i} + B_{1i}(\text{daily natural scenery exposure})_{di} + B_{2i}(\text{daily human–animal interaction})_{di} + \varepsilon_{di}$
Level 2	$B_{0i} = \gamma_{00} + \gamma_{01}(\text{average natural scenery exposure})_{i} + \gamma_{02}(\text{average human–animal interaction})_{i} + \mu_{0i}$ $B_{1i} = \gamma_{10} + \mu_{1i}$ $B_{2ii} = \gamma_{20} + \mu_{2i}$

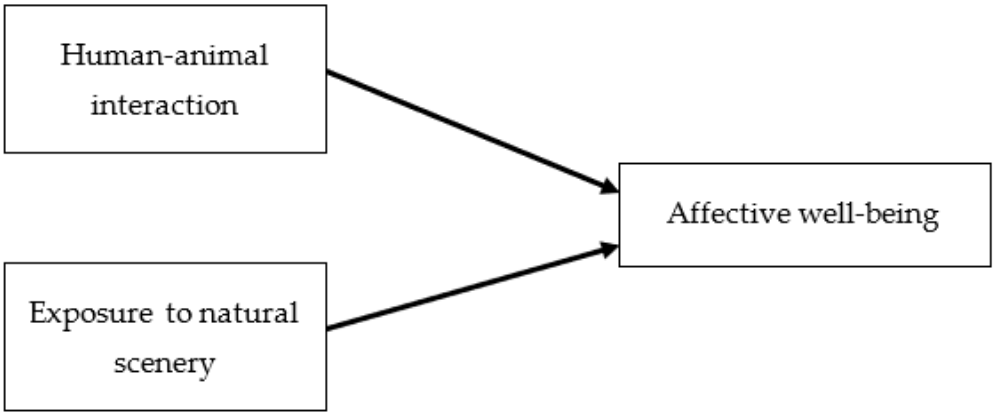

Figure 1. Conceptual Diagram Illustrating the Additive Model. Note: The model represents a conceptual diagram illustrating the additive model of the hypothesis.

We tested the fourth hypothesis that human–animal interaction would moderate the relationship between natural scenery exposure and well-being (Figure 2), such that the relationship between natural scenery exposure and well-being would vary by whether human–animal interaction occurred, using a multiplicative model:

	Multiplicative Model
Level 1	$(\text{Daily well-being})_{di} = B_{0i} + B_{1i}(\text{daily natural scenery exposure})_{di} + B_{2i}(\text{daily human–animal interaction})_{di} + B_{3i}(\text{daily natural scenery exposure} \times \text{daily human–animal interaction})_{di} + \varepsilon_{di}$
Level 2	$B_{0ii} = \gamma_{00} + \gamma_{01}(\text{average natural scenery exposure})_{i} + \gamma_{02}(\text{average human–animal interaction})_{i} + \gamma_{03}(\text{average natural scenery exposure} \times \text{average human–animal interaction})_{i} + \mu_{0i}$ $B_{1ii} = \gamma_{10} + \mu_{1i}$ $B_{2ii} = \gamma_{20} + \mu_{2i}$ $B_{3ii} = \gamma_{30}$

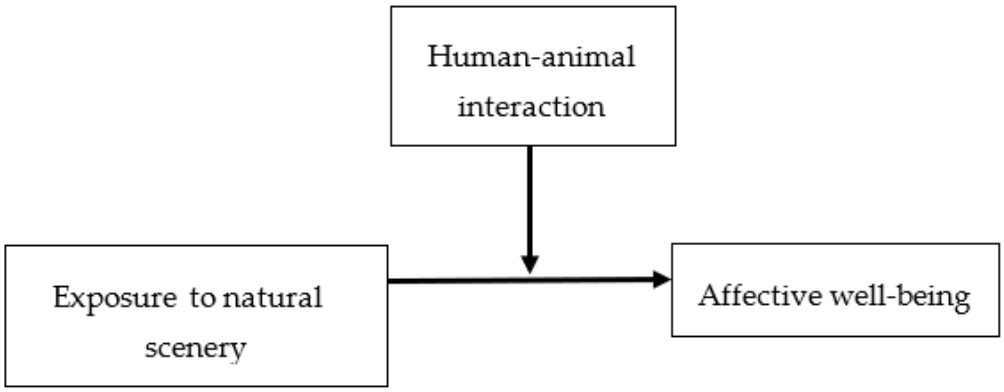

Figure 2. Conceptual Diagram Illustrating the Moderation Model. Note: The model represents a conceptual diagram illustrating the moderation model of the hypothesis.

The fourth model uses similar parameters to the first two hypotheses with the addition of interaction terms, where the within-person parameter of interest γ_{30} indicates the multiplicative relationship between natural scenery exposure and human–animal interaction in influencing well-being (i.e., how much the relationship between natural scenery exposure and well-being changes in relation to human–animal interaction). The corresponding between-person parameter of interest is γ_{03}.

In instances where the models have convergence failure or singular fit issues, we reduced the model by removing the random slope component.

2.4. Transparency and Openness

The current study's design and its analysis plan were not pre-registered. The relevant materials, dataset, and R analytic code have been made publicly available on ResearchBox (#805; https://researchbox.org/805). All analyses were conducted in R version 4.2.1 [42]. Descriptives were calculated using psych version 2.2.5 [43]. Scale reliabilities were calculated using lavaan version 0.6-11 with semTools version 0.5.6 [44,45]. Multilevel modelling was conducted using lme4 version 1.1.30 [46], and significance testing was carried out via lmerTest version 3.1.3 [47]. Effect sizes were calculated in the form of standardised coefficients for fixed effects using effectsize version 0.7.0 with the "pseudo" method [48]. The zero-order correlations between all Level 2 variables are available as Supplementary Materials in Researchbox #805".

3. Results

3.1. Natural Scenery and Affective Well-Being

First, we found significant associations between natural scenery exposure and positive affect at both the within-person level (γ_{10} = 0.09, SE = 0.01, ß = 0.20, 95% CI = [0.16, 0.24], $p < 0.001$) and the between-person level (γ_{01} = 0.10, SE = 0.02, ß = 0.22, 95% CI = [0.13, 0.31], $p < 0.001$), such that there was a small positive relationship between natural scenery exposure and positive affect (Table 2). These results suggest that within each individual, higher levels of positive affect are observed on days with higher levels of natural scenery exposure (vs. days with lower levels of natural scenery exposure), and in addition, between individuals, individuals who generally have higher levels of natural scenery exposure (vs. individuals who generally have lower levels of natural scenery exposure) also have higher levels of positive affect in general.

Table 2. Multilevel Analysis Results for Natural Scenery Exposure and Stress, Negative Affect and Positive Affect.

	Stress				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			3.25	0.09	<0.001
Level 2 (Between-person)					
Natural scenery exposure, γ_{01}	−0.03	[−0.12, 0.06]	−0.03	0.05	0.548
Level 1 (Within-person)					
Natural scenery exposure, γ_{10}	−0.03	[−0.07, 0.004]	−0.05	0.03	0.083
Random effects					
Intercept, μ_{0i}			3.20		
Slope of natural scenery exposure, μ_{1i}			0.05		
	Negative Affect				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			0.56	0.02	<0.001
Level 2 (*Between-person*)					
Natural scenery exposure, γ_{01}	−0.04	[−0.13, 0.05]	−0.01	0.01	0.377
Level 1 (*Within-person*)					
Natural scenery exposure, γ_{10}	−0.03	[−0.07, 0.004]	−0.01	0.007	0.082
Random effects					
Intercept, μ_{0i}			0.21		
Slope of natural scenery exposure, μ_{1i}			0.004		
	Positive Affect				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			1.93	0.03	<0.001
Level 2 (*Between-person*)					
Natural scenery exposure, γ_{01}	0.22	[0.13, 0.31]	0.10	0.02	<0.001
Level 1 (*Within-person*)					
Natural scenery exposure, γ_{10}	0.20	[0.16, 0.24]	0.09	0.009	<0.001
Random effects					
Intercept, μ_{0i}			0.48		
Slope of natural scenery exposure, μ_{1i}			0.006		

Note: ß = effect size or standardised coefficient; 95% CI = 95% confidence interval of ß; γ = unstandardised coefficients; *SE* = standard error. Random effect values indicate variances.

In contrast, we did not find any evidence for significant associations between natural scenery exposure and negative affect nor between natural scenery exposure and stress, at both the within- and between-person levels (Table 2).

3.2. Human–Animal Interaction and Affective Well-Being

We found significant associations between human–animal interaction and positive affect in the human–animal interaction model at the within-person level (γ_{10} = 0.24, SE = 0.05, ß = 0.14, 95% CI = [0.08, 0.21], $p < 0.001$), such that there was a small positive relationship between human–animal interaction and positive affect, but not at the between-person level (Table 3). These results suggest that within each individual, higher levels of positive affect are observed on days with human–animal interaction (vs. days without human–animal interaction).

Table 3. Multilevel Analysis Results for Human–animal Interaction and Stress, Negative Affect and Positive Affect.

	Stress				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			3.25	0.09	<0.001
Level 2 (*Between-person*)					
Human–animal interaction, γ_{01}	−0.05	[−0.16, 0.06]	−0.32	0.34	0.345
Level 1 (*Within-person*)					
Human–animal interaction, γ_{10}	−0.002	[−0.06, 0.06]	−0.10	0.17	0.942
Random effects					
Intercept, μ_{0i}			3.22		
Slope of human–animal interaction, μ_{1i}			0.55		
	Negative Affect				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			0.57	0.02	<0.001
Level 2 (*Between-person*)					
Human–animal interaction, γ_{01}	0.006	[−0.10, 0.11]	0.01	0.08	0.908
Level 1 (*Within-person*)					
Human–animal interaction, γ_{10}	−0.03	[−0.09, 0.02]	−0.04	0.04	0.250
Random effects					
Intercept, μ_{0i}			0.21		
Slope of human–animal interaction, μ_{1i}					
	Positive Affect				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			1.89	0.03	<0.001
Level 2 (*Between-person*)					
Human–animal interaction, γ_{01}	−0.01	[−0.11, 0.09]	−0.03	0.12	0.822
Level 1 (*Within-person*)					
Human–animal interaction, γ_{10}	0.14	[0.08, 0.21]	0.24	0.05	<0.001
Random effects					
Intercept, μ_{0i}			0.51		
Slope of human–animal interaction, μ_{1i}			0.08		

Note: ß = effect size or standardised coefficient; 95% CI = 95% confidence interval of ß; γ = unstandardised coefficients; *SE* = standard error. Reduced model was run for negative affect. Random effect values indicate variances.

In contrast, we did not find any evidence for significant associations between human–animal interaction and negative affect nor between human–animal interaction and stress, at both the within- and between-person levels (Table 3).

3.3. Additive Associations with Well-Being

From the additive model, we found significant associations between natural scenery exposure and positive effect at both the within-person level (γ_{10} = 0.09, SE = 0.009, ß = 0.19, 95% CI = [0.15, 0.23], $p < 0.001$) and the between-person level (γ_{01} = 0.09, SE = 0.02, ß = 0.20, 95% CI = [0.11, 0.29], $p < 0.001$), such that there was a small positive relationship between natural scenery exposure and positive affect. Furthermore, we also found significant associations between human–animal interactions and positive affect at the within-person level (γ_{01} = 0.20, SE = 0.05, ß = 0.12, 95% CI = [0.06, 0.18], $p < 0.001$) such that there was a small positive relationship between human–animal interaction and positive affect, but not at the between-person level.

In contrast, we did not find any evidence for significant associations between natural scenery exposure and negative affect nor between natural scenery exposure and stress, at both the within- and between-person levels. Furthermore, we did not find any evidence for significant associations between human–animal interaction and negative affect nor between human–animal interaction and stress, at both the within- and between-person levels (Table 4).

Table 4. Multilevel Analysis Results for the Additive Model Predicting Stress, Negative Affect and Positive Affect.

	Stress				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			3.25	0.09	<0.001
Level 2 (*Between-person*)					
Natural scenery exposure, γ_{01}	−0.02	[−0.12, 0.07]	−0.02	0.05	0.648
Human−animal interaction, γ_{02}	−0.05	[−0.16, 0.05]	−0.33	0.33	0.327
Level 1 (*Within-person*)					
Natural scenery exposure, γ_{10}	−0.03	[−0.07, 0.00]	−0.05	0.02	0.074
Human–animal interaction, γ_{20}	−0.003	[−0.06, 0.06]	0.02	0.17	0.903
Random effects					
Intercept, μ_{0i}			3.23		
Slope of natural scenery exposure, μ_{1i}			0.049		
Slope of human–animal interaction, μ_{2i}			0.616		
	Negative Affect				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			0.57	0.02	<0.001
Level 2 (*Between-person*)					
Natural scenery exposure, γ_{01}	−0.03	[−0.13, 0.06]	−0.01	0.01	0.493
Human−animal interaction, γ_{02}	0.008	[−0.09, 0.11]	0.01	0.08	0.874
Level 1 (*Within-person*)					
Natural scenery exposure, γ_{10}	−0.03	[−0.07, 0.005]	−0.01	0.007	0.089
Human–animal interaction, γ_{20}	−0.03	[−0.09, 0.03]	−0.04	0.04	0.308
Random effects					
Intercept, μ_{0i}			0.22		
Slope of natural scenery exposure, μ_{1i}			0.004		
Slope of human–animal interaction, μ_{2i}			0.007		
	Positive Affect				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			1.90	0.03	<0.001
Level 2 (*Between-person*)					
Natural scenery exposure, γ_{01}	0.20	[0.11, 0.29]	0.09	0.02	<0.001
Human−animal interaction, γ_{02}	−0.03	[−0.12, 0.07]	−0.06	0.12	0.595
Level 1 (*Within-person*)					
Natural scenery exposure, γ_{10}	0.19	[0.15, 0.23]	0.09	0.01	<0.001
Human–animal interaction, γ_{20}	0.12	[0.06, 0.18]	0.20	0.05	<0.001
Random effects					
Intercept, μ_{0i}			0.49		
Slope of natural scenery exposure, μ_{1i}			0.007		
Slope of human–animal interaction, μ_{2i}			0.07		

Note: ß = effect size or standardised coefficient; 95% CI = 95% confidence interval of ß; γ = unstandardised coefficients; *SE* = standard error. Reduced models were run for stress and negative affect. Random effect values indicate variances.

3.4. Multiplicative Associations with Well-Being

From the multiplicative models, we did not find evidence for human–animal interaction as a moderator of the relationship between natural scenery exposure and positive affect, between natural scenery exposure and negative affect, nor between natural scenery exposure and stress, at both the within- and between-person levels (Table 5).

Table 5. Multilevel Analysis Results for the Moderation Model Predicting Stress, Negative Affect and Positive Affect.

	Stress				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			3.25	0.09	<0.001
Level 2 (*Between-person*)					
Natural scenery exposure, γ_{01}	−0.03	[−0.12, 0.07]	−0.03	0.06	0.597
Human–animal interaction, γ_{02}	−0.05	[−0.16, 0.06]	−0.30	0.35	0.385
Natural scenery exposure × human–animal interaction, γ_{03}	−0.008	[−0.10, 0.08]	−0.03	0.20	0.868
Level 1 (*Within-person*)					
Natural scenery exposure, γ_{10}	−0.03	[−0.07, 0.01]	−0.04	0.03	0.127
Human–animal interaction, γ_{20}	−0.002	[−0.06, 0.06]	−0.008	0.17	0.961
Natural scenery exposure × human–animal interaction, γ_{30}	−0.0008	[−0.04, 0.04]	−0.003	0.07	0.968
Random effects					
Intercept, μ_{0i}			3.22		
Slope of natural scenery exposure, μ_{1i}					
Slope of human–animal interaction, μ_{2i}			0.56		
	Negative Affect				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			0.56	0.02	<0.001
Level 2 (*Between-person*)					
Natural scenery exposure, γ_{01}	−0.04	[−0.13, 0.05]	−0.01	0.01	0.389
Human–animal interaction, γ_{02}	−0.009	[−0.12, 0.10]	0.01	0.08	0.870
Natural scenery exposure × human–animal interaction, γ_{03}	0.07	[−0.03, 0.16]	0.07	0.05	0.176
Level 1 (*Within-person*)					
Natural scenery exposure, γ_{10}	−0.04	[−0.08, 0.01]	−0.01	0.007	0.096
Human–animal interaction, γ_{20}	−0.03	[−0.09, 0.03]	−0.04	0.04	0.329
Natural scenery exposure × human–animal interaction, γ_{30}	0.007	[−0.04, 0.05]	0.005	0.02	0.739
Random effects					
Intercept, μ_{0i}			0.21		
Slope of natural scenery exposure, μ_{1i}			0.004		
Slope of human–animal interaction, μ_{2i}					
	Positive Affect				
Predictors	**ß**	**95% CI**	**Unstd. est.**	***SE***	***p***
Fixed effects					
Intercept, γ_{00}			1.90	0.034	<0.001
Level 2 (*Between-person*)					
Natural scenery exposure, γ_{01}	0.21	[0.12, 0.29]	0.09	0.02	<0.001
Human–animal interaction, γ_{02}	−0.02	[−0.12, 0.08]	−0.04	0.12	0.716
Natural scenery exposure × human–animal interaction, γ_{03}	−0.04	[−0.14, 0.06]	−0.05	0.07	0.456
Level 1 (*Within-person*)					
Natural scenery exposure, γ_{10}	0.19	[0.14, 0.23]	0.09	0.01	<0.001
Human–animal interaction, γ_{20}	0.12	[0.06, 0.18]	0.20	0.05	<0.001
Natural scenery exposure × human–animal interaction, γ_{30}	0.01	[−0.03, 0.06]	0.016	0.023	0.491
Random effects					
Intercept, μ_{0i}			0.49		
Slope of natural scenery exposure, μ_{1i}			0.007		
Slope of human–animal interaction, μ_{2i}			0.07		

Note: ß = effect size or standardised coefficient; 95% CI = 95% confidence interval of ß; γ = unstandardised coefficients; *SE* = standard error. Reduced models were run for stress and negative affect. Random effect values indicate variances.

4. Discussion

With the growing interest in the psychological benefits of nature in our daily lives, our current study examines an understudied yet necessary research question—what are the additive and multiplicative contributions of natural scenery exposure and human–animal interaction to affective well-being (i.e., positive affect, negative affect, and stress)? Using a daily diary approach with multilevel analyses, our methodology enhanced both the ecological and internal validity of the current study [29], which enabled us to critically untangle the effects of natural scenery exposure and human–animal interaction on affective well-being.

Several findings in our study were noteworthy. Firstly, the results support our first hypothesis, indicating a significant non-trivial small to medium positive association between natural scenery exposure and positive affect in within-person analyses. The findings demonstrate that on days where participants are exposed to more natural scenery, they were more likely to experience higher positive affect when compared to days when participants were exposed to less natural scenery. Moreover, we also found a significant non-trivial small to medium positive association between natural scenery exposure and positive affect in between-person analyses, suggesting that participants who were exposed to more natural were more likely to have higher positive affect when compared to participants who had lower exposure to nature scenery. These findings are consistent with previous literature that found that exposure to natural scenery was positively associated with an increase in well-being [49,50]. Our finding of a significant within-person association contributed to the existing literature by ruling out the possibility that the association between natural scenery and positive affect is confounded by stable individual differences. Nonetheless, our study did not find a significant association between exposure to natural scenery and negatively valanced well-being indicators such as stress and negative affect, suggesting that the benefits of natural scenery exposure are limited to positively valanced well-being indicators such as positive affect. Additionally, the daily diary method does not manipulate stress in our participants prior to the survey, indicating that the participants might not have undergone stress for Stress Reduction Theory to take effect.

Secondly, consistent with our second hypothesis, we found a significant non-trivial small to medium positive within-person association between human–animal interaction and positive affect. The findings demonstrate that on days where participants interacted with animals, they were more likely to experience an increase in positive affect compared to days when participants did not interact with animals. The results support previous research where an increase in positive affect was observed after interacting with animals [27]. However, similar to exposure to natural scenery, the association between human–animal interaction and negatively valanced well-being indicators such as stress and negative affect were not significant. Taken together, the results suggest that exposure to nature, which consists of viewing natural sceneries and human–animal interactions, may benefit in increasing positive affect but is less likely to decrease existing negative affect.

Thirdly, our exploratory multilevel moderation analysis showed no significant interaction between human–animal interaction and natural scenery exposure on well-being outcomes. The lack of interaction suggests that the relationship between human–animal interaction and natural scenery exposure is additive rather than multiplicative. The additive relationship implies that natural scenery exposure and human–animal interaction each have unique effects on well-being outcomes. Thus, it is likely that the mechanisms underlying the effect of natural scenery exposure and human–animal interaction on well-being outcomes are distinct. Nature, according to Stress Reduction Theory may increase well-being through restorative effects of natural environments to invoke positive responses such as feeling relaxed and calm [12]. In contrast, the well-being benefits of human–animal interaction are likely to be reliant on the role of oxytocin in regulating emotions and increasing social behaviours [16–19,22].

Our study is not without caveats. Firstly, our study has a restricted demographic, as the sample were university students from Singapore. Singapore is a unique context, as the country attempts to integrate and consistently maintain nature together with our urban city [51,52]. Given that not all natural environments may have similar psychological benefits [53–55], our study might not be generalisable to other studies that have landscapes that are different from Singapore. Moreover, the sample comprises of more females than males and no older adults, who show more positive attitudes towards animals compared to men [56]. Henceforth, future research can take note of the proportion of female participants and young adults to encourage generalisability. Secondly, although the current study employs a longitudinal design, the correlational nature of our design may limit causal inferences. Thus, the current study may still be vulnerable to potential reverse causation and time varying confounds [57–59]. Thus, future research can add value to our data through experimental designs to manipulate the presence of natural scenery and human–animal interaction to demonstrate its effects on well-being. Thirdly, considering that negative events with animal contact might not occur often, future studies should consider increasing the time period of the daily diary study for greater significant impact.

5. Conclusions

The present study adds value to the understudied literature on the relations between natural scenery and human–animal interaction. Using a large-scale daily diary study, our study supports the additive relations between natural scenery exposure and human–animal interaction and highlights their distinct mechanisms in promoting affective well-being.

Supplementary Materials: The following supporting information can be downloaded at: ResearchBox (#805; https://researchbox.org/805&PEER_REVIEW_passcode=TMKEKX), where you can find the relevant materials, dataset, and R analytic code of the current study, as well as the zero order correlation table.

Author Contributions: Conceptualization, A.Y.H.G., S.M.C., N.M.M. and A.H.; writing—original draft preparation, A.Y.H.G., S.M.C.; writing—review and editing, A.Y.H.G., S.M.C., N.R.Y.C., N.M.M. and A.H.; supervision, N.R.Y.C., N.M.M. and A.H.; funding acquisition, N.M.M. and A.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by grants awarded to Andree Hartanto by Singapore Management University through research grants from the Ministry of Education Academy Research Fund Tier 1 (20-C242-SMU-001 & 21-SOSS-SMU-023) and Lee Kong Chian Fund for Research Excellence.

Institutional Review Board Statement: The study was approved by the Institutional Review Board (or Ethics Committee) of Singapore Management University (IRB-20-118-A075-M3(121); IRB-20-118-A075-M4(621)).

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

Data Availability Statement: The data availability statement can be downloaded at: ResearchBox (#805; https://researchbox.org/805).

Conflicts of Interest: The authors declare no conflict of interest.

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