

Virtual Nature: The effect of mystery, spaciousness, and nature-based sounds on young adults

Emre Sarpkaya, s2276631

Department of Psychology, University of Twente

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Prof. Dr. G. J. Westerhof, Kars Otten

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Abstract

Social well-being can be promoted by having conversations and bonding socially. Nature (virtual) has proven that it can have many positive effects and generate associations that can be used as conversational material. Thus, the study focused on which parts of nature and whether nature videos can generate (the most) associations. High mystery, low spaciousness, and background-sound assisted videos are expected to score the highest. The hypotheses were tested using a mixed methods approach. For this study, the results of 55 participants (18-22 years old) were analyzed. Together with the control condition, the manipulation of mystery (low vs high) and spaciousness (low vs high) resulted in five different conditions. All five categories were tested with and without sound. Participants were divided into one of two conditions (sound vs without sound). The results indicate that there was no significant difference among the different nature conditions ($p>0.05$), but significant differences among some nature conditions and the control condition were found ($p<0.05$). For the number of associations, low mystery, high spaciousness, and low spaciousness had a significant difference with the control condition. For personal engagement, high mystery and low spaciousness were significantly different from the control conditions. Additionally, the ease of storytelling was higher for the without sound condition, which contradicts earlier assumptions. Concludingly, the assumptions that high mystery, low spaciousness, and background-sound assisted videos were expected to score the highest, were rejected. However, further research with more polarizing and valid nature images that represent each nature category is needed.

Key words: Young adults, social well-being, storytelling, virtual nature, mystery, spaciousness

Introduction

Virtual nature & social well-being

Social well-being can be defined as the evaluation of one's circumstance and functioning in society (Keyes, 1998). It is an important factor when it comes to life satisfaction. Thus, increasing social well-being is important and could help alleviate negative feelings and increase well-being among all age groups. There are many ways to increase social well-being, one of which is increasing social aspirations through nature related sceneries such as videos and images (Bratman et al., 2019). These virtual nature-related

elements can then positively influence social aspirations which could lead to increased social well-being if acted upon. Virtual nature can be defined as technological nature, meaning, technologies that in various ways simulate and enable the experience of the natural world (Litleskare et al., 2020). Virtual nature is important, because it can mediate the effects of real nature, without real nature being present (Litleskare et al., 2020). This might be helpful because it could increase the connectivity of humans with nature, in world where the connection to real nature is declining (Bratman et al., 2019). By acknowledging the link between (virtual) nature and social well-being, this study focuses on confronting young adults with different elements of virtual nature to generate associations that can serve as conversational material and promote social bonding.

Increasing social interactions among individuals is important and can be achieved through elements of nature. Rapid urbanization and the consequential decline in human contact with nature pose a great risk to human well-being (Bratman et al., 2019). Growing evidence is revealing the importance of nature when it comes to mental well-being (Bratman et al., 2019). Nature has been proven to be helpful when it comes to therapeutic sessions that aim at reducing adverse reactions that can lead to anxiety (Aghaie et al., 2014). Nature experience has also been associated with reducing major risk factors for mental illness and depression such as sleep problems and stress (Bratman et al., 2019). Disconnectedness and social isolation are hard to deal with, especially among older adults (van Houwelingen-Snippe, Allouch, & van Rompay, 2022). However, research has shown that nature interaction can increase perceived social support and stimulate social connectedness, indicating that nature could be an effective factor in social well-being (van Houwelingen-Snippe, Allouch, & van Rompay, 2022). Thus, the effect of (virtual) nature on social well-being and its related emotions could have great clinical implications and must be researched further.

Nature connectedness & personal engagement

The effect of (virtual) nature on social well-being is scientifically studied, but it begs the question of how exactly nature is related to social well-being and social interactions. One finding suggests that nature connectedness is an important factor when it comes to the relationship between nature and social well-being (Howell, Dopko, Passmore, & Buro, 2011). Nature connectedness refers to the degree to which people include nature as part of their identity (Capaldi, Dopko, & Zelenski, 2014). In the context of this paper, nature connectedness is especially important because it can help individuals come up with different associations that can serve as conversational material to further their social well-being when

interacting with different individuals. Although nature-relatedness is very important, it will not be included in the final analysis, because previous studies have confirmed its role in social well-being thoroughly. Thus, because of this importance, data on nature-relatedness will be collected to be controlled for, but not analyzed any further.

Nature environments can lead to different associations that can serve as conversational material, however, because environments in nature vary thoroughly, it can be difficult to pinpoint the exact aspects of nature that lead to certain associations. Thus, it is important to further investigate which elements of nature lead to the most associations to effectively create nature environments that generate the highest number of associations. The study of Schertz et al. (2018) concludes that scenes that resemble nature more closely are linked more strongly to associations about spirituality and life. Conversations are especially socially valuable if they are intimate because intimate conversations can lead to better social bonding (Leckfor, 2020). The depth of conversational topics account for the intimacy level of topics, which include themes of family problems, life ambitions and one's deepest fears. Thus, the intimacy level of associations with nature is also relevant when creating nature environments. Both the number of associations and level of intimacy of associations are of great meaning when creating nature environments that are supposed to induce long-lasting and intimate conversations with individuals. Thus, it is important to distinguish and further investigate which specific characteristics of nature environments lead to both intimate and a high number of associations.

The benefits of (virtual) nature

Because nature is known to manifest associations in people, it is also important to know how nature distinguishes from virtual nature. Virtual nature enables more possibilities when creating nature-related experiments because it can be easily manipulated through programs such as photoshop or 3D development platforms such as Unity3D. In real nature, on the other hand, individuals would have to move great distances to find substantially different environments. Thus, virtual nature makes it easy to put concrete elements in and out of nature environments. Although the study of White et al. (2018), states that real nature environments are preferred to simulated nature environments, they indicate that virtual nature should be used in situations where contact with real nature is not possible. The study of Litleskare et al., (2020) concludes that virtual nature environments are developing towards a point where they might be able to simulate exposure to real nature. They also argue that virtual nature should not be viewed as a replacement for real nature, but instead as an addition that can help people

to reconnect with real nature. Virtual nature can also be used to pre-test specific effects of nature environments that can later be used in real nature settings. Another study supports the claim that virtual nature can have similar beneficial effects like the exposure to real nature (Valtchanov, 2010). Thus, it can be concluded that virtual nature has the benefit of editability and can produce similar positive effects like real nature.

Spaciousness and Mystery in nature environments

Nature environments can have multiple positive effects, but they beg the question of which elements nature environments can be divided into. One approach by Kaplan and Kaplan (1989) suggests that elements of nature within the Attention Restorative Theory (ART) can be categorized into four subgroups, namely soft fascination, mystery, spaciousness, and compatibility. According to the study of Otten et al. (2022a), controlling for both high mystery and low spaciousness led to the most associations among elderly people. Additionally, other important elements of nature are nature-based sounds. Nature-based sounds can help to assist certain therapeutic sessions to achieve positive effects for patients and thus could assist initiating social bonding (Aghaie et al., 2014). In the following, the categories of mystery and spaciousness will be combined with nature-based sounds to form fitting hypotheses.

Mystery is one of the key elements within the Attention Restorative Theory by Kaplan and Kaplan (1989). It is described as stimulating curiosity and exploration by hinting that there is more to experience if one would walk further into the nature environment. Examples can include elements that obscure the visibility of the scene such as hills that partly block the visibility of the horizon or night-times. Additional elements can be pathways that are integrated into the scenery without an obvious destination. The study of Otten et al. (2022a), indicated that a high level of mystery leads to the most associations among elderly people.

Storytelling

Now that it is clear, that the effects of virtual nature can be compared to those of real nature, the question arises of how virtual nature can help to create new social bonds and elicit conversations. Research has shown that stories can create and promote empathy, which is an important factor when bonding with others and strengthening existing bonds (Anderson & Keltner, 2002; Hibbin, 2016). Story creation and storytelling have been known to strengthen the bonds between people, and parties because they can be emotional and enable a means of insight into a person's thoughts (Kaufman, 2003). Thus, the question arises, which specific

elements of these stories are the key to these social benefits? When telling stories, storytellers can include personal information which helps revealing parts of their personality to others (Westerhof & Bohlmeijer 2012). Because storytelling is known to elicit empathy, strengthen the relationship between people and promote new social bonds, the personal information shared in such stories, could be the cause of these social benefits (Anderson & Keltner, 2002; Cohen, 1998; Hibbin, 2016). Concludingly, social benefits such as strengthening existing bonds and promoting new social bonds are known to be caused by storytelling. Specifically, personal information shared in such stories could be the cause of these findings.

Personal information that can be included in stories shared by individuals, could be the cause of social benefits such as social bonding. However, it is important to acknowledge the role of (virtual) nature in this context, and whether (virtual) nature can encourage individuals to elicit stories that include personal information. Previous studies have shown that nature can elicit personal engagement and positive associations (Otten et al., 2022a; Otten et al., 2022b). Thus, it can be concluded that virtual nature could elicit personal information in stories through personal engagement and positive associations. Now that it is clear that stories can elicit social benefits and that virtual nature is capable of eliciting such stories, it is important to specify the factor that distinguishes a story that generates social improvements from a story that does not generate social improvements. According to the study of Baroni (2014), it is of great importance that stories are worthwhile telling to elicit and improve social connectedness. Thus, recognizing the importance of stories being worthwhile to tell, this factor will be measured across three variables and included in the final hypothesis: *Ease of storytelling, valence, and social intentions*. Stories that are easier to write might be more worthwhile to share with others. Valence and social intentions could play a crucial role as well, because positively valenced memories can lead to enjoyable social interactions (O'Rourke et al., 2017). Valence can be defined as the quality of an event such as an event with intrinsic "good"-ness (positive valence) or "bad"-ness (negative valence) ("Valence (psychology),"2022)). Social intention was chosen as the most important variable because it correlates best with promoting social bonding, which complies with the goal of this study.

Hypothesis H1 A high level of mystery in virtual nature leads to a higher number of associations, easier to write, more positive, easier to share, more personal and longer stories among young adults.

Spaciousness can be described as the visibility in a scene such as the number of objects that can be found (Kaplan & Kaplan, 1989). Elements of spaciousness can be

demonstrated by the number of trees (tree density) in each scenery. The study of Otten et al. (2022a), indicated that a low level of spaciousness, meaning a high number of trees, lead to the most associations among elderly people.

Hypothesis H2 A low level of spaciousness in virtual nature leads to a higher number of associations, easier to write, more positive, easier to share, more personal and longer stories among young adults.

Nature-based sounds are sounds that can be found within nature scenes. Such sounds can include both relaxing sounds such as the soothing sound of a soft wind or rather aggressive sounds of animals such as the grunting of a bear. Soothing sounds of nature have been found to be relaxing and helpful within certain therapeutic sessions (Aghaie, 2014). Because these sounds have been shown to help with relaxations and show positive effects in therapeutic sessions, it is expected generate more personal and positive stories (and associations). Additionally, adding sounds is hypothesized to trigger a higher number of associations because of the additional stimulus present. Thus, it is hypothesized that these soothing nature-based sounds that accompany nature scenes could lead to more (personal) associations.

Hypothesis H3 A high level of nature-based sounds in virtual nature leads to higher number of associations, easier to write, more positive, easier to share, more personal and longer stories among young adults.

Methods

Research Design

This study used a randomized factorial design to investigate the quantity and type of associations of young adults when presented to specific elements of virtual nature through an online survey. To keep the length of the individual sessions short, each participant was presented with four virtual nature scenes and one control scene of an urban city. Half of the participants were presented with five images and the other half were presented with five images that were accompanied by nature-based and urban-city-based background sounds. All five images were distinct to ensure that participants could differentiate between the scenes. Each participant was randomly chosen to be in one of two conditions and the order of images was randomly selected. The participants of each condition had to imagine and write down a story they associated with each scene and had to indicate which emotions fitted best for each





scene. Additionally, their nature connectedness was assessed through a simple multiple-choice questionnaire at the end of the study.

Stimuli

The VN scenes were searched for online, by visually matching the categories of spaciousness and mystery to the respective scenes. *Mystery* was defined by the presence of a narrow pathway that leads into the forest without a clear destination and objects within the scene that blocked other elements (Kaplan & Kaplan, 1989). On the other hand, *spaciousness* was defined by the number of elements that could be counted in each scenery (Kaplan & Kaplan, 1989). A pilot study with nine responses was conducted to test the correlation of each image which the respective categories of mystery and spaciousness. Results suggested that each image fitted the respective category (see Appendix A). For the nature-based background sounds, a 33-seconds long mp3 file was chosen that consisted of distant bird sounds. The participants of the control condition were shown a scene of an urban city area with trees, that was accompanied by urban city sounds. The background sounds for the respective scenes were retrieved from freesound.org and were chosen based on the keywords “urban city”. The images and sound files were then merged into an MP4 file. To ensure similarity between the conditions, every image and mp4 file was cut to the same size.

Table 1

Stimuli: Nature scenes controlled for low or high spaciousness and mystery

	Variable (high or low)	
Category	High Spaciousness	Low Spaciousness
		
Category	High Mystery	Low Mystery
		

Category	Control
	

Note. Images were tested for each category through a pilot study (see Appendix A)

Participants

Participants were recruited via the Sona Study Systems and were students from the University of Twente. The online survey allowed for a higher number of participants because it provided a lower work threshold. After all, participants could take part from home. Additionally, participating through mobile devices was declined because the images might not have been displayed as intended. The total number of participants that started the survey were 84. 29 participants were excluded due to declined consent or discontinuing the online survey. Thus, the final analysis included only 55 out of 84 participants (30 participants for the without sound condition; 25 participants for the with sound condition). Recorded demographics were age, gender, nationality, highest educational degree, the current study, nature opportunities, and nature-relatedness. The table below displays the percentage of each demographical characteristic. According to the table, the student population did not differ significantly from each other ($p > .1$). Interestingly, 72.7% of participants were psychology students and between the age of 20 to 25. Additionally, participants were mostly female (65.5%) and German (67.3%).

Table 2

Demographical and descriptive data of participants across age, gender and nationality, study subject, nature-relatedness, nature opportunities; displayed in percentage for both the video and picture group

Category	Condition						X^2	df	P
	Without Sound (N = 30)			With Sound (N = 25)					
	Age								
	<i>Below 20</i>	<i>20-25</i>	<i>26-30</i>	<i>Below 20</i>	<i>20-25</i>	<i>26-30</i>			
%	30.0	70.0	0.0	12.0	88.0	0.0			
N	9	21	0	3	22	0			

Category	Gender						.9	1.0	.351
	<i>Male</i>	<i>Female</i>	<i>Other</i>	<i>Male</i>	<i>Female</i>	<i>Other</i>			
%	40.0	60.0	0.0	28.0	72.0	0.0			
N	12	18	0	7	18	0			
Category	Nationality						1.2	2.0	.544
	<i>German</i>	<i>Dutch</i>	<i>Other</i>	<i>German</i>	<i>Dutch</i>	<i>Other</i>			
%	63.3	23.3	13.3	72.0	12.0	16.0			
N	19	7	4	18	3	4			
Category	Study subject						1.6	2.0	.439
	<i>Psychology</i>	<i>C. Sc.</i>	<i>Other</i>	<i>Psychology</i>	<i>C. Sc.</i>	<i>Other</i>			
%	73.3	20.0	6.7	72.0	12.0	16.0			
N	22	6	2	18	3	4			
Category	Nature-relatedness						2.3	1.0	.126
	Low (5-13)	Mid (14-21)	High (>22)	Low (5-13)	Mid (14-21)	High (>22)			
%	0.0	56.7	43.3	0.0	36.0	64.0			
N	0	17	13	0	9	16			
Category	Nature opportunities						3.2	2.0	.204
	Low (0-1)	Mid (2-3)	High (4-6)	Low (0-1)	Mid (2-3)	High (4-6)			
%	23.3	73.4	3.3	36.0	52.0	12.0			
N	7	22	1	9	13	3			

Note: C. Sc stands for Communication Sciences

Procedure & Materials

Participants were greeted with an introduction to the survey and asked for consent to process their information. Afterwards, demographic information such as age and gender were collected. Later, participants were randomly assigned to one of two conditions: Each condition consisted of either five images or five videos (images accompanied by background sound). Both the sound and without sound condition shared the same sceneries, which included four nature scenes and one city scene (control condition). The only difference was whether the images were accompanied with fitting background sounds (sound condition) or were presented as stand-alone images (without sound condition). The soundtracks used for the sound condition were 33 seconds long. For the nature scenes, the audio consisted of distant bird chirps. For the city scene, the soundtrack represented an urban city and consisted of traffic and walking sounds.

For the first task, participants had to imagine walking through the scenery while talking to someone. They were then asked to write a short story about what they would be talking about, such as feelings and thoughts from the present, past, and future. The second task consisted of assigning multiple (or a singular) emotions to the scene. The third task included participants to answer a few questions about the story they had just written. Participants had to assign certain emotions to the story, indicating how difficult it was to write the story. Lastly, participants had to indicate whether they would use their story to deepen or strengthen certain relationships with people. All three tasks were repeated for each of the five scenes.

At the end of the study, participants had to shortly indicate their nature connectedness on a scale from one to five by indicating how much they agreed or disagreed with the presented statements. In total, they were presented with six different statements such as “My connection with nature is an important part of who I am” and “When I’m outside I always have an eye for animals”.

Outcome measures

Associations

Associations were measured using one dependent variables: *number of associations*, *personal engagement*, and *story length*. The number of associations was measured using quantitative data.

The *Number of associations* was measured using the multiple-choice question: ‘Which of the answers below do you think best fits the nature scene? You can click on multiple answers.’ Based on the findings of Hendriks et al. (2016), the following words were chosen: Having fun, having social contact, relaxing and restful, feeling useful (e.g., walking a dog, gardening, caring for animals), feeling healthy and fit, nostalgia, admire nature, feeling of freedom. Additionally, participants could also choose ‘*other*’ and provide a feeling of their own. The variables were measured dichotomously and the score of each participant consisted of the total number of options they chose (minimum of 0; maximum of 9). Thus, choosing more options meant a higher number of association score for the respective category.

Storytelling characteristics

Storytelling characteristics were measured using five dependent variables: *ease of storytelling*, *valence*, *social intentions*, *personal engagement* and *story length*. The data for ease of storytelling, valence and social intentions were obtained from quantitative data when

participants were asked to indicate their response on a 5-point scale and multiple-choice question. Personal engagement and story length was measured using qualitative data. Qualitative data was collected through a text box where participants had to write a short story after viewing the image or video.

Ease of storytelling was measured by specifying whether it was hard or easy to write the story for the given scene on a 5-point scale. Additionally, the results, indicating the difficulty level to write a story for each scene, could be used as a sign for a high or low number of associations that were made for each scene.

Valence was measured with the Positive and Negative Affect Schedule (PANAS) using five emotions for both the positive (pride, overjoyed, enthusiastic, inspired, determined) and negative (nervous, upset, anxious, ashamed, restless) categories (Engelen et al., 2006). Participants were asked to indicate how well each emotion fits the story they had written on a 5-point scale: (1) hardly or not at all fits, (2) fits a bit, (3) fits average, (4) fits well, (5) fits very well. For both negative and positive emotions, a sum score between 5 and 25 was calculated. A high score indicates a more positive or negative valence. A low score, respectively, indicates a less positive or negative valence.

Social Intention of each story was measured by assessing whether participants would use each story to strengthen their relationships. To assess the social intention of each story, participants had to indicate on a 5-point scale how much they agree with each statement: “(I would use the story I just wrote down to-) develop more trust in a relationship”, “for more closeness in contact with someone else”, “to share memories and keep friendships alive”, “to invite someone to tell more about themselves”.

Personal engagement (emotional depth) was measured based on an ordinal variable across five levels (1-5): (1) no engagement (e.g., empty text field), (2) observation (e.g., “There are trees”), (3) affective judgment (e.g. “pretty flowers”), (4) utilization (e.g., “jogging” or “sleeping”) and (5) personal reflection (e.g., “I see me and my girlfriend spending time here” or “I get reminded of my father when I look at this image”). The personal engagement score resulted from the emotional depth of a story.

Story length was measured based on the number of words within the text. The story-length score consisted of the sum of total words used within that story.

Covariates

Nature-relatedness was measured using a short version of the Nature-Relatedness Scale, to assess the nature connectedness of participants (Nisbet, Zelenski, & Murphy, 2009;

Nisbet and Zelenski, 2013). The scale consisted of six items such as “When I'm outside I always have an eye for animals” and “I feel very connected to all living beings and the earth”. The total possible nature scores (five to 25) were divided into three groups, namely low (5-13), mid (14-21) and high (>22).

Available nature opportunities (quantity) were measured by choosing out of six nature options: none, nearby park, nearby nature area, private garden, private balcony, communal garden, and other. The total number of available options (seven) was divided into three groups, namely low (0-1), mid (2-3) and high (4-6).

Analysis

First, the number of participants for each demographical category such as age, gender, nationality, study subject, nature-relatedness and nature opportunities were compared between the with sound and without sound condition (table 2). The difference among each category was compared using a Cross-Tabulation Chi-Square test. None of the categories had significantly different numbers of participants among both conditions (table 2). Personal engagement and story length were recorded as qualitative data and later transformed into quantitative data. For the analysis, the different nature elements were tested for both sphericity and equal variance. When Mauchly's test of sphericity was violated, the Greenhouse-Geisser correction was used. If the Levene-test of equal variance was violated, the corrected values within the output tables of the t-test were used. Story elements and associations across mystery and spaciousness were tested in a within-subject analysis (repeated measures ANOVA and post-hoc Bonferroni test). The difference between story elements and associations among the sound and without sound conditions were tested in a between-subject setting (t-test). In total, 275 sentences were transformed into quantitative data using the five categories as described in the outcome measures section. The analysis was performed with the help of SPSS version 27 and a set confidence interval of 95%.

Results

The following tables show the results of the analysis. Table three and four include the mean, standard deviation, and the results of the ANOVA test for the mystery, spaciousness and control conditions. Table five, shows the mean, standard deviation, and the results of the t-test for the sound and without sound condition. The hypotheses were assessed using three independent conditions with a Bonferroni adjusted alpha level of .016. For hypothesis H1 and H2, repeated measures ANOVA with three conditions (high, low, and control) were

performed and repeated for all variables. Hypothesis H3 was measured by comparing the mean of all variables across the sound and without sound conditions with a t-test.

Hypothesis H1

For ‘Number of associations’, there was a significant difference between the means across mystery (Table 3). The Bonferroni test ($MD = .7$, $SD = .2$, $p = .032$) suggests that the control condition was significantly different from the mean of the low mystery condition. This means that participants in the low mystery condition had significantly more associations than the control condition. There was no significant difference between the control condition and the high mystery condition and between the high mystery and low mystery conditions.

For ‘Average *Personal engagement*’, there was a significant difference between the means across mystery (Table 3). The Bonferroni test ($MD = .2$, $SD = .1$, $p = .033$) suggests that the mean of the control condition is significantly different from the mean of the mystery high condition.

This means that participants in the high mystery condition had significantly more associations than the control condition. There was no significant difference between the control condition and the low mystery condition and between the high mystery and low mystery conditions.

For the other variables, there was no significant difference between the conditions, meaning that hypothesis H1 ‘a high level of mystery in virtual nature leads to a higher number of associations, easier to write, more positive, easier to share, more personal and longer stories among young adults’ must be rejected. The difference of at least two conditions between high mystery, low mystery, and control condition were not significant for the following categories: ease of storytelling, positive valence, negative valence, social intention, and story length. For these categories, the ANOVA results showed a p-score of at least $p = .078$.

Table 3

Mean scores across mystery

Category	High mystery	Low mystery	Control	F-value	P-value
Number of associations	3.4 (1.6)	3.4 (1.9)*	2.7* (1.5)	$F(2.0, 108.0) = 4.5$	.013
Ease of Storytelling	3.9 (.9)	3.7 (1.0)	4.0 (.9)	$F(1.8, 97.1) = 2.7$	.078

Positive valence	3.4 (.9)	3.5 (.8)	3.4 (1.0)	$F(1.8, 95.4) = 2.2$	.779
Negative valence	4.3 (.8)	4.3 (.9)	4.3 (.9)	$F(2.0, 108.0) = .1$	.930
Social intention	3.5 (1.0)	3.4 (1.0)	3.5 (.9)	$F(2.0, 108.0) = 1.1$	.345
Personal engagement	4.7 (.7)*	4.6 (.7)	4.5 (.7)*	$F(2.0, 106.0) = 3.7$	.029
Story length	44.7 (27.7)	43.5 (32.2)	45.1 (28.3)	$F(2.0, 108.0) = .2$	.855

Note: For high mystery and low mystery: The numbers equal the mean score. The numbers within brackets equal the standard deviation. The ‘*’ symbol indicates that the marked numbers show a significant difference among each other for that specific row ($p < 0.05$).

Hypothesis H2

For ‘Number of associations’, there was a significant difference between the means across spaciousness (Table 4). The Bonferroni test suggests that the control condition was significantly different from the mean of the spaciousness high condition ($MDZ = .7$, $SD = .2$, $p = .019$) and spaciousness low condition ($MDZ = .8$, $SD = .2$, $p = .002$). This means that participants in the high spaciousness and low spaciousness conditions had significantly more associations than the control condition. However, there was no significant difference between the high and low spaciousness conditions.

For ‘Average *Personal engagement*’, there was a significant difference between the means across spaciousness (Table 4). The Bonferroni test ($MDZ = .3$, $SD = .1$, $p = .002$) suggests that the mean of the control condition is significantly different from the mean of the low spaciousness condition. This means that participants in the low spaciousness condition had significantly more personal engagement than the control conditions. There was no significant difference between the high spaciousness and control conditions and between the high spaciousness and low spaciousness conditions.

For the other variables, there was no significant difference between the conditions, meaning that hypothesis H2 ‘a low level of spaciousness in virtual nature leads to a higher number of associations, easier to write, more positive, easier to share, more personal and longer stories among young adults’ must be rejected. The difference of at least two conditions between high spaciousness, low spaciousness and control conditions were not significant for the following categories: ease of storytelling, positive valence, negative valence, social

intention, and story length. For these categories, the ANOVA results showed a p-score of at least $p = .133$.

Table 4

Mean scores across spaciousness

Category	High spaciousness	Low spaciousness	Control	F-value	P-value
Number of associations	3.4* <i>a</i> (1.5)	3.5* <i>b</i> (1.6)	2.7,* <i>ab</i> (1.5)	$F(2.0, 108.0) = 7.8$	0.001
Ease of Storytelling	4.0 (.9)	4.0 (.8)	4.0 (.9)	$F(1.8, 96.6) = 0.0$	.959
Positive valence	3.4 (.7)	3.3 (.9)	3.4 (1.0)	$F(2.0, 108.0) = .3$	.714
Negative valence	4.5 (.8)	4.4 (.8)	4.3 (.9)	$F(2.0, 108.0) = .6$	.539
Social intention	3.7 (.9)	3.8 (.9)	3.5 (.9)	$F(2.0, 108.0) = 2.0$	.133
Personal engagement	4.7 (.7)	4.8 (.4.0)*	4.5 (.7)*	$F(2.0, 108.0) = 8.4$	<.001
Story length	74.9 (144.2)	53.1 (30.5)	45.1 (28.3)	$F(1.0, 55.9) = 1.8$	.181

Note: For high spaciousness and low spaciousness: The numbers equal the mean score. The numbers within brackets equal the standard deviation. For ‘number of associations’ there is a significant effect between the high spaciousness condition and control condition, as well as the low spaciousness condition and the control condition. There is no significant difference between the high and low spaciousness conditions. The ‘**a*’ and ‘**b*’ symbols indicate that the marked numbers with the same symbol show a significant difference from each other for that specific row ($p < 0.05$).

Hypothesis H3

For the effect of sound, a significant difference was found for ‘Ease of storytelling’ (see Table 5). This means that participants found it easier to write a story in the without sound condition, which contradicts the assumptions of the third hypothesis. For the other variables, there was no significant difference between the sound conditions, meaning that hypothesis H3 ‘a high level of nature-based sounds in virtual nature leads to higher number of associations, easier to write, more positive, easier to share, more personal and longer stories among young adults’ must be rejected. The difference between the mean scores were not significant for the

following categories: positive valence, negative valence, social intention, number of associations, personal engagement, and story length. For these categories, the t-test results showed a p-score of at least $p = .141$.

Table 5

Mean score for video and picture conditions across all categories

Category	Without sound	With Sound	T-value	P-value
Number of associations	3.2 (1.3)	3.7 (1.3)	$t(53.0) = 1.5$	.141
Ease of storytelling	4.0* (.4)	3.7* (.8)	$t(36.6) = -2.3$	.029
Positive valence	3.3 (.6)	3.5 (.7)	$t(53.0) = 1.2$	.239
Negative valence	4.4 (.6)	4.3 (.6)	$t(53.0) = -.7$	.497
Social intention	3.7 (.5)	3.5 (1.0)	$t(32.7) = -1.1$	.288
Personal engagement	4.7 (.6)	4.7 (.5)	$t(53.0) = .5$	.649
Story length	49.1 (34.7)	60.1 (52.4)	$t(53.0) = .9$	.357

Note: For sound and without sound condition: The numbers equal the mean score. The numbers within brackets equal the standard deviation. The ‘*’ symbol indicates that the marked numbers show a significant difference among each other for that specific row ($p < 0.05$).

Discussion

Summary of findings

The findings show that all three hypotheses were rejected. For hypotheses H1 and H2, no significant difference between low or high mystery and low or high spaciousness could be measured. Instead, the analysis indicates that low mystery, high spaciousness, and low spaciousness lead to significantly higher results for the number of associations than the control condition (tables 3 and 4). Additionally, the analysis indicates that high mystery and low spaciousness lead to significantly higher results for personal engagement than the control

condition. This means that these nature conditions, experienced a significant effect of nature elements compared to the control condition for the number of associations and personal engagement. Thus, it can be concluded that the results of this study indicate that some nature settings can have a significantly higher effect on people compared to non-nature settings. Regardless, hypotheses H1 and H2 must be rejected because a significant effect among the nature settings themselves, could not be measured.

For hypothesis H3, only one significant difference between the sound and without sound condition could be measured. However, this result contradicts the original assumption of hypothesis H3 that the sound conditions will have a significantly higher score for ease of storytelling. The analysis indicates that the ease of storytelling (table 5) is significantly higher for the without sound condition than for the sound condition. For all other categories such as the number of associations, personal engagement, positive valence, negative valence, social intention and story length, there was no significant results among both conditions. Thus, it can be concluded that hypothesis H3 must be rejected and that the participants in the without sound condition had significantly higher scores for ease of storytelling, which contradicts earlier assumptions.

Reason for rejection of the hypotheses

A reason for the rejection of the hypothesis H1 could be the different target condition of young adults. The study of Otten et al. (2022a) performed the study on older adults which led to significant findings for manipulating mystery. Because young adults are more extroverted and open, and might thus be more explorative, manipulating mystery might not have resulted in a significant difference among the target audience (Donnellan & Lucas, 2008). By being very explorative and thus sensible to explorative settings in general, young adults might react very similarly to nature images regardless of their mystery level. However, what the analysis did confirm instead is that young adults do have a significantly different reactions to nature environments compared to urban environments, regardless of the level of mystery and spaciousness. It is important to note that this significant difference was only found for the category of number of associations and personal engagement. Thus, it might be that older adults react more strongly to nature element manipulation compared to young adults. Further research is needed to confirm these findings.

An alternative reason for the rejection of all three hypotheses could be that the images that were chosen to represent each nature category were not valid. Due to time constraints only a very small pilot study was conducted that confirmed the categorization of each image,

however, the study might have to be conducted with a higher sample size to confirm the findings (see Appendix A). Because the images were not manually created through a 3D building program but rather selected via google search results for 'nature scenes', it was not possible to guarantee the total isolation of the nature elements for spaciousness and mystery. This means that the image for a respective category could contain elements of another category, which might eliminate polarizing differences among the images. For example, the images for the mystery condition could also contain elements of spaciousness and the image for the spaciousness could contain elements of mystery. The possible presence of spaciousness in both low and high mystery, might have reduced or eliminate within-subject differences for mystery. The possible presence of mystery in both low and high spaciousness, might have reduced or eliminate within-subject differences for spaciousness. Additionally, alternative nature elements such as leaf color, leaf form and tree type could not be singled out and controlled for which might have influenced the study results. This possible lack of isolation of nature elements for each image, might be one possible explanation for the lack of significant within-subject difference among the mystery and spaciousness conditions. The only significant differences were found between some control condition and some nature conditions, but not among the nature conditions themselves. This could mean that the image for the control condition is significantly different to the nature images, but that the nature images are not distinct enough to generate significant differences from each other. The possible lack the polarizing of the nature images could mean that the nature images were too similar to each other, which might also explain why there is no significant difference between mystery and spaciousness conditions, but only a significant difference among the nature categories and the control condition of an urban city. In conclusion, it might be of interest to confirm the isolation of nature elements for each nature category to yield possible significant differences among low and high mystery and low and high spaciousness.

Another possible reason for the findings could be the outcome measure. It could be that the scale used to assess social intention was not valid, as it was quite short, containing only four questions. The study of Niemi et al. (1986) concluded that the lengths of a scale can influence its validity. Increasing the scale length can also increase validity (Niemi et al., 1986). Thus, expanding the scale lengths for social intention could also increase its validity. Additionally, the transformation of story length from qualitative data to quantitative data could be measured differently. One alternative approach to measure story length might be to count the number of nouns, verbs, adjectives, and pronouns instead of counting the words per story. The number of words could be an inaccurate measurement of story length, as the

content of the stories was not considered. Thus, the validity of the measurement systems should be checked and alternated for future studies.

Additionally, the findings indicate that the ease of storytelling was significantly lower in the sound condition which contradicts the original assumption of hypothesis three. The initial (part of the) hypothesis that the participants in the condition with sound would have higher scores on ease of storytelling must be rejected. The study of Furnham and Bradley (1997) concluded that background music can have significant effects on task-performance. Although the background music used for the nature images were bird sounds which were selected to represent real nature settings, it could have acted as a distraction because of the extra stimuli present. This distraction could have then made it harder to write the story, possibly also due to a decrease in task-concentration.

Meaning of results for virtual nature, storytelling, and social well-being

For virtual nature, the results indicate that virtual nature can significantly affect the storytelling characteristics. It can be used to both increase the number of associations and increase the emotional depth within some stories (personal engagement). Some virtual nature scenes do significantly differ from control scenes such as urban settings and lead to more associations and personal engagement within some stories. This means that virtual nature could assist conversation generation and social bonding, which might in turn positively affect social well-being.

Strengths and limitations

Online study setting

The study was conducted in an online setting which resulted in both strengths and limitations of the study. Multiple things worked out without hindrance due to the online study. Although many participants did not finish the survey, the ones that finished had no missing data in between each question. This achievement could be partly explained by the deliberate notice that participants could only receive their sonar credit points if they completed the entire study. Thus, participants might have been extra careful to not miss any steps along the way. Additionally, the online survey program (Qualtrics 2022) warned participants if they have missing information on a page, which might have further increased the completeness of each finished questionnaire.

Due to the ease of accessibility to participants and covid-19 regulations, it was also easier to conduct the study in an online setting. However, this resulted in less control for the

study environment. Participants had to log in through their computers and fill out the survey. Thus, the environment for each participant could not be controlled for (e.g., house, university, crowded, quiet). Additionally, because of the lack of physical contact between each participant and the study advisor, a highly anonymized environment was created which might have led to less sincere answers due a lack of responsibility (Milgram, 1963; Ong & Weiss, 2000). Further, the videos consisted of still images that were accompanied by nature-based sounds, which could bore the participants due to the lack of movement in each scenery. Thus, participants might not fully watch and skip parts of the video, especially toward the end of the study.

Additionally, the research was conducted to find out whether virtual nature could generate conversational material that could stimulate conversations. However, the study was not conducted in a conversation eliciting environment. Instead, participants had to write down their initial thoughts and indicate their feelings. Thus, the study might generate different results if it is conducted by having participants communicate in small conditions after exposure to virtual nature.

Real vs generated images

The images that were chosen for each category were based on real-life images instead of 3D-generated environments. This was a strength in so far, that the participants were presented with realistic nature environments instead of possible low-quality images due to a lack of programming knowledge with 3D programs. Additionally, images were chosen based on total image size (pixel size) so they could later be adjusted to the same size. The size of each image for each nature category was adjusted to 1200x800, which ensured homogeneity. Thus, the image size was successfully controlled for without suffering image quality deficiencies. Further, creating images through a 3D program requires a certain skill set, which might have delayed the study. However, using 3D programs could still be beneficial because it allows more variables to control for such as leaf color, general image colors and leaf size. These 3D programs can be especially useful when they are hyper-realistic such as in real nature settings.

Recommendations for future research

To control for a higher number of elements in each scenery, the images should be generated in a 3D program and not selected among pre-existing images. Differences in each scenery such as background colors, tree species, and leaf color could then be controlled for,

which might result in more accurate findings. However, if the researchers decide to use images of real nature, it is advised to conduct a larger and more complex pilot study. The pilot study should not only check whether the images fit the chosen nature element (high or low mystery and spaciousness). The pilot study should also check whether the images exclude certain nature elements to ensure the polarizing nature of each image. This might lead to significant differences between low and high mystery or low and high spaciousness.

Additionally, images should be generated with a hyper-realistic engine, which might resemble real nature more accurately and thus might also increase accuracy in findings. Lastly, the research could focus on virtual reality (VR) which provides additional sensory stimulation and makes the VN setting feel more realistic and the experience more immersive (Rubio-Tamayo, 2017).

Research about virtual nature that generates associations to elicit conversations, should be ideally conducted in a group or peer-to-peer setting instead of a single-participant online study. Eliciting conversations and generating associations might differ in a peer-to-peer environment and might feel more natural, which could result in different findings.

Conclusion

The findings of this study indicate that there was no significant difference among the real nature scenes between low and high mystery or low and high spaciousness. However, there was a significant difference between some nature conditions and the control conditions. For the number of associations, low mystery, high spaciousness, and low spaciousness had a significant difference with the control conditions. For personal engagement, high mystery and low spaciousness were significantly different from the control conditions. These results confirm earlier assumptions of previous studies that nature settings can have a significantly higher effect than none-nature settings on generating associations and emotional depth. Additionally, the difference between the sound and without sound condition were not significant, except for the value of the ease of storytelling. The ease of storytelling was higher for the without sound condition, which contradicts earlier assumptions. Future research should focus on maximizing the exclusion of other nature elements in each nature image so that the differences among the nature images are as high as possible. Additionally, future research should check the validity of whether each nature image represents each nature category appropriately. Furthermore, additional research is required to confirm the findings among the nature, sound- and without-sound conditions.

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Appendix A

Table 1A. Pilot study.

Score for each nature image; Scale 1-5

Participant	HighSpc.	LowSpc.	HighMyst.	LowMyst.
1	4	1	5	2
2	5	1	3	1
3	4	1	5	2
4	5	2	4	1
5	5	1	5	2
6	4	1	4	1
7	4	1	5	3
8	5	1	4	2
9	3	1	5	1
Mean score	4,3	1,1	4,4	1,6

Note: A low number either indicates low mystery or low spaciousness, whereas a high number indicates either high mystery or high spaciousness. ‘HighSpc.’ represents high spaciousness. ‘LowSpc.’ represents low spaciousness. ‘HighMyst.’ represents high mystery. ‘LowMyst.’ represents low mystery.