



Exploring VR as a Method to Study User Perceptions of Challenges in Green Transition Technology in Nature

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Abstract. In this paper, we explore Virtual Reality (VR) as a tool for user studies assessing nature perceptions. We collect user perceptions of green transition technology in nature, and compare a natural landscape and one with windmills, both as paper and VR representations, in a user study ($n = 14$). Our salient findings indicate that while VR provides more immersive and engaging experiences, paper-based visualizations allow more freedom for the user's own imagination and reflections on personal experiences on green technologies in nature. Moreover, in VR, the participants tend to get more distracted by the visual details, for instance the implausibilities of the virtual world. The landscape without windmills was perceived as more positive (PANAS) and more restorative (PRS).

Keywords: nature · HCI · virtual reality · user studies · user experience · green transition · sustainability

1 Introduction

Nature connection has been reported to improve both physical and mental health and wellbeing [45, 46], and also emerging technologies have been utilized for fostering this connection [12, 38]. This paper explores the use of VR in assessing user perceptions of nature landscapes and compares how people perceive a natural landscape with a landscape containing built technology. Our research contribution is two-fold. Firstly, we investigate the method of using VR for assessing human perceptions of natural landscapes and compare the approach to paper-based visual presentations of nature landscapes. Secondly, we explore people's perceptions of integrating a green transition technology, windmills, into the landscape visualizations. The motivation of our research lies in evaluating and developing research methods to assess technology-mediated nature experiences.

Our work is partially motivated by the global trend of green transition, which includes setting up new large-scale technological solutions [41]. As we increasingly seek sustainable solutions to address environmental concerns, technologies

such as windmills become a visible part of the landscape in many places. Despite their environmental benefits, these technologies harm the local natural ecosystems by replacing nature with a constructed environment, and affecting animals such as reindeer [36] and birds [22]. The green energy constructions also alter the visual and experiential qualities of natural environments. This raises the question about green transition technologies' impact on nature engagement and experience. Thematically, our research is part of a larger discussion of just transition for the green transition, highlighting the complex nature of sustainable technologies, green transition, and the effects on local and larger societal frameworks [16, 23].

More research is needed on participatory design for pluriversal perspectives on sustainability. VR can be a useful tool in the domain, and its suitability for such studies needs to be evaluated. As the contribution of our work, we report the pros and cons of using VR compared to paper-based visualizations of nature landscapes without and with technology constructions. By exploring the methodologies to investigate green transition, we pave the way to better user research methods and research tools for citizen participation in green transition decision-making.

2 Related Work

2.1 HCI and Nature Experiences

In the area of Human-Computer Interaction, the combination of nature experiences and technology has been investigated from different viewpoints. Webber et al. [43] have presented typologies in use technology for nature engagement, and bring up dimensions of directness and distance in nature engagements. These dimensions of directness include direct, abstracted, and simulated nature experiences. It has been highlighted that technology has the potential to enhance engagement with nature, promoting wellbeing and awareness of natural environments as well as its fragility [12]. However, designing technology for nature encounters requires addressing the balance between support and intrusiveness, especially in mobile contexts, where devices can both enhance and disrupt the user's interaction with nature and outdoors [28].

VR and AR technologies can contribute to linking individual users with environmental issues by providing immersive experiences for learning, increasing users' self-efficacy, and influencing behavior change [8]. However, while technology enables simulated nature experiences, it often lacks the multisensory qualities of authentic nature. For connecting with nature, extended reality (XR) technologies have been used for immersive experiences with nature [10], embodying animals in immersive virtual environments [1], and for gamified experiences for environmental awareness [34]. A systematic literature review of 80 papers focusing on VR and AR with environmental sustainability revealed that most commonly the technologies were used for education and learning purposes, followed by promoting ecological behavior [8] such as for behavioral change in plastic consumption [5].

There is no single definition of VR. The field is dynamically evolving due to new research, developing technologies, and expanding application possibilities. Classical definitions of VR include, e.g. “real-time interactive graphics” [7]. However, many scholars consider VR as a broader concept [2]. Milgram and Kishino’s virtuality continuum raises discussion on the distinction between real and virtual [29]. Kardong-Edgren et al. suggests immersion and presence as a way to define VR [20]. Since higher immersion results in higher presence, it is an important factor in the VR experience. Among the various VR definitions, three features are common: immersion, presence, and interaction with the virtual environment [7]. VR technology encompasses non-immersive, semi-immersive, and fully immersive spaces depending on the degree of presence and used equipment [9, 11]. Non-immersive VR utilizes screens to deliver the VR experience. In this case, the virtual world does not obscure the real world and users do not feel complete presence in the scene [11, 33]. Also, only some of a user’s senses are stimulated. Semi-immersive experiences, e.g. a flight simulator combining both physical and virtual elements [7, 11]. Fully immersive VR creates an illusion of “being there” by replacing the physical surroundings and making the person feel like they are present in the virtual world [9, 31]. Typically, fully immersive VR is presented through head-mounted displays (HMD) and interaction is enabled via hand-held controllers. thus the definition of VR can slightly vary between different sources and use situations. Therefore, in this study, VR relies on a broader definition of virtual reality including non-interactive viewing of 360 pictures through an HMD.

2.2 Nature Connectedness

Humans have an evolution-based need to feel the connection with nature [21, 44]. That concept is called biophilia-love of life, which Wilson [21, 44] defines as the desire to connect with living beings and the natural environment. This natural tendency of humans urges them to seek connections with nature and other forms of life, including a longing to be close to nature and a preference for things that resemble it. Richardson and Butler [32] emphasize the problem of how biophilic properties commonly remain superficial in practical design projects as the most important result of biophilic design, i.e. a deeper and stronger connection with nature, is often overlooked.

Nature connectedness is defined as an individual’s perceived relationship with the natural world [26]. Often it is discussed in a context of pro-environmental behavior [37], a variety of health and wellbeing outcomes, and overall happiness [4]. The basis for nature connectedness is created in childhood, but even short experiences in nature can increase connection with nature in adults [35]. A study by Calogiuri et al. [3] demonstrates that using 360 videos and computer-generated scenarios to create immersive virtual nature, can be equally effective in increasing nature connectedness, as long as the same level of immersion and interaction is offered.

Studies have presented that nature connectedness has a significant effect on health, wellbeing, and happiness [4]. Wang et al. [40] report that forest environ-

ments presented using VR video can alleviate stress to some extent. Although an artificial environment is not as effective in relieving stress physically as a natural environment, it can still relieve stress psychologically. The use of static 360 videos from peaceful natural locations with local cultural context and minimal visible or audible human influence is an effective approach when designing virtual natural environments for stress reduction [17].

2.3 Restoration and Measuring the Affect

One approach to studying the various positive effects of nature is restoration. Restoration means recovery from stress, and renewal of a person's physical, psychological, and social resources, which have decreased due to adaptation to stress factors triggered by the environment [13, 19]. According to Ulrich et al.'s [39] Stress Reduction Theory (SRT), nature, green spaces, and images of nature support restoration. Attention Restoration Theory (ART) suggests that spending time in nature or viewing it can improve mental fatigue and concentration [18]. According to ART, restorative experiences consist of four elements: being away, fascination, coherence, and compatibility. These four categories are used as a base of the Perceived Restorative Scale (PRS), which is a tool developed by Hartig et al. [14] to measure the restorative quality of environments. One of the main goals is to give planners a measurement tool that could be used to assess the effects of current and future spaces. The scale uses ART properties as measurement attributes. The object is evaluated according to 16 statements with a seven-point scale.

Another scale commonly used to evaluate feelings is the Positive and Negative Affect Schedule (PANAS) developed by Watson et al. [42]. This mood scale consists of 20 words, half of which measure positive affect and the other half negative affect. Each item is rated on a five-point scale. Because the PANAS is a self-report questionnaire, it can be inaccurate in assessing people's mood. The answer is always subjective and depends on the reviewer's interpretation of the word and their ability to estimate their feelings. Also, not every word applies to every type of situation, so it must be taken into account when analyzing the results.

When estimating the restorative qualities of the environment, several measurements are often combined to gain a broader understanding of the factors affecting the entire experience. The research of Mattila et al. [27] examined the effects of restorative experiences in an immersive virtual reality forest environment by using the Subjective Vitality Scale (SVS), Positive and negative Affect Schedule (PANAS), Restoration Outcome Scale (ROS) and Perceived Restoration Scale (PRS). The results showed that the VR environment and a real forest were generally as restorative, but the virtual environment was perceived as more fascinating and coherent. Often virtual reality is considered to be a better method than traditional 2D media in delivering audiovisual stimuli. However, researchers have differing findings about the restorative effectiveness of VR when compared with nature photos or actual physical nature [24].

3 Research Method

3.1 Study Set-up

The Virtual Nature Environment. The study used two different scenarios of nature environments generated by AI (Fig. 1). SkyboxAI was used to create the 360 image. The used prompt was: Northern Europe Forest landscape, European spruce, European red pine, birch, blue river with waterfall, subshrub, lush plants. The idea was to generate a virtual nature environment that resembled the environment that the subjects were used to seeing. After three rounds of generation, the result was satisfying enough. However, AI wanted to include mountains and vegetation that might distance the virtual nature from the natural setting of the study area. A 360 picture was then edited in Adobe Photoshop. Using Photoshop's generative fill tool the environment was modified. The used prompt was: Wind turbines park. This time the AI tool had some issues completing the task. The wind turbines were distorted and too small. After seven rounds of generation, the best option was chosen from the 21 edited images. The image quality deteriorated during the editing process, although the 360 perspective remained intact. Also, the picture itself was quite provocative, changing the landscape significantly from the unedited version (lack of trees and mountains). Both mentioned factors were expected to affect the VR experience.

Questionnaire with PANAS and PRS. In the study, two different scales were used to evaluate the experience. Positive and negative Affect Schedule (PANAS) [42] and Perceived Restoration Scale (PRS) [14] Both scales were offered in English and with the subjects' native language. As the scales are commonly used in studies exploring the restoration of virtual and real environments, they were deemed as suitable for comparing a virtual nature experience through VR and from the 2D printed image. In PANAS there were 10 positive words and 10 negative words that respondents estimated in what extent the virtual nature made them feel that emotion, on a five-point Likert scale where 1=Not at all/very slightly; 5= Extremely. The total score is calculated by finding the sum of the 10 positive items, and then the 10 negative items. Scores range from 10–50 for both sets of items. For the total positive score, a higher score indicates more of a positive affect. For the total negative score, a lower score indicates less of a negative affect. [42]

Four elements Being away, Fascination, Coherence, and Compatibility of Perceived Restoration were measured on a seven-point Likert scale with sixteen statements. (1=Not at all; 7=Completely). After each section, the respondent was asked to explain in a few words the reasons that made them feel the way they had described above.

The scenarios were shown to the subjects in two forms, as a 360° image in VR via a head-mounted display and a 2D image printed on A4-sized paper, Fig. 3. Subjects could hold the picture in their hand during the evaluation. The VR headset was the Meta Quest 3, ensuring sufficient graphical fidelity and field of view, which was connected wirelessly to a computer. The participants had no



Fig. 1. AI generated virtual environment, left Scenario A, right Scenario B

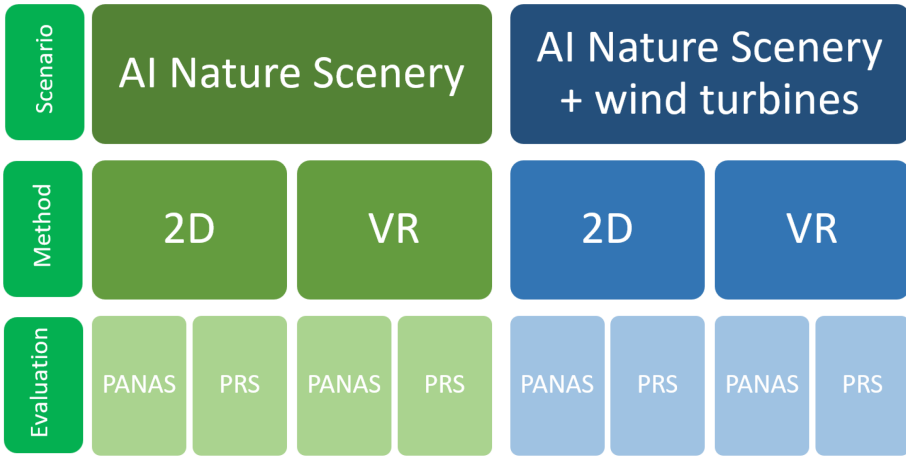


Fig. 2. Study structure

interaction with the software, with a researcher changing the images remotely using the pc when the participant indicated that they were ready to move to the next image. The wireless connection induced no significant latency that would affect the user experience. Half of the subjects were shown VR first (Fig. 2). After spending 5–10 min exploring the VR environments (scenario A and scenario B), the participants evaluated their experience using PANAS and PRS, and filled out the questionnaire on a computer. The other half of the subjects started by viewing 2D printed versions of the same scenarios and completing a paper version of the same questionnaires. The time participants spent in the study varied from 30 min to two hours, with an average of 45 min. The scenarios were shown to all the participants in the same order, scenario A first and scenario B second.

3.2 Participants

In total, the study included 14 participants (seven men, six women, and one non-binary person), with the ages between 18–24 (2/14), 25–34 (9/14), 35–44 (2/14), and 45–54 (1/14), with affiliation in different disciplines of design. Considering



Fig. 3. Left a participant evaluation of the environment from a picture. Right a participant watching the scenery in VR.

their familiarity with VR, one had tried VR once, 4/14 a few times (1–5), and 9/14 had used VR more than five times.

4 Results

4.1 Comparing Scenarios Without (A) and with (B) Windmills

Statistical tests were run separately for positive and negative datasets (PANAS). First, a non-parametric Friedman test was conducted to examine whether there were significant differences in participant responses across the different scenarios and viewing methods: A 2D, A VR, B 2D, and B VR. The results of the Friedman test indicated a significant difference between the conditions, $\chi^2(3) = 29.82$, $p < .001$. Similarly, the results of the negative dataset indicated a significant difference between the conditions, $\chi^2(3) = 24.93$, $p < .001$. To further investigate these differences, pairwise comparisons were conducted using Wilcoxon Signed-Rank Tests with a Bonferroni correction applied to account for multiple comparisons ($\alpha = 0.0083$). The results are presented in Table 1.

On average, participants associated more positive words towards nature with minimal human impact than nature with extensive human impact. Figure 4 illustrates how scenario A without windmills scored higher (3.53; 3.86) on the positive affect schedule than scenario B with windmills (2.32; 2.38) Table 2. Scenario A was also perceived as less negative (1.32; 1.31) than scenario B (2.34; 2.19). The difference between positive and negative affect was seen in the case of scenario A where positive affect surpasses 3.5 and negative affect stays under 1.5. On the contrary, scenario B was perceived almost as positive as negative. Generally, VR versions of the scenarios were perceived slightly more positively and less negatively than the 2D version in both scales. However, in the case of VR version of scenario B there is great dispersion between answers.

Table 1. Significant Pairs

Dataset	Scenario 1	Scenario 2	Statistic	p-value	Significant ($p < 0.0083$)
Positive	A 2D	A VR	13.0	0.040921	False
Positive	A 2D	B 2D	0.0	0.002200	True
Positive	A 2D	B VR	5.0	0.001221	True
Positive	A VR	B 2D	0.0	0.000122	True
Positive	A VR	B VR	0.0	0.000122	True
Positive	B 2D	B VR	38.0	0.936938	False
Negative	A 2D	A VR	10.0	0.495868	False
Negative	A 2D	B 2D	0.0	0.002209	True
Negative	A 2D	B VR	0.0	0.003346	True
Negative	A VR	B 2D	1.0	0.002852	True
Negative	A VR	B VR	1.0	0.002852	True
Negative	B 2D	B VR	16.0	0.439659	False

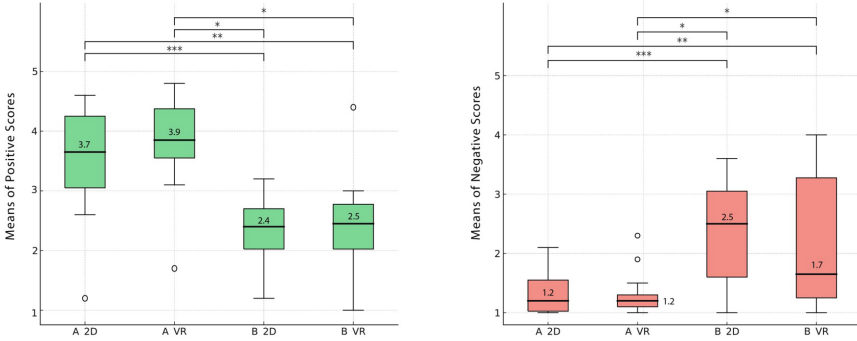


Fig. 4. Boxplot of Positive and Negative Affect Schedule in scenarios A and B with VR and 2D ($n = 14$); Significant Pairs $*$ ($p = 0.0001$), $**$ ($p = 0.001$), $***$ ($p = 0.002$)

Table 2. Statistics (PANAS)

	Dataset	A 2D	A VR	B 2D	B VR
Mean	Positive	3.528571	3.857143	2.321429	2.378571
Median	Positive	3.650000	3.850000	2.400000	2.450000
Standard Deviation	Positive	0.940072	0.805476	0.609134	0.842321
Mean	Negative	1.321429	1.307143	2.342857	2.192857
Median	Negative	1.200000	1.200000	2.500000	1.650000
Standard Deviation	Negative	0.355568	0.370995	0.922967	1.125552

With PRS, the VR version got higher scores in each category, Fig. 5. The greatest difference was with coherence, where the difference between VR and 2D was 0.9 in scenario B and 0.78 in scenario A. Overall, scenario B was evaluated as more confusing, distracting and chaotic than scenario A. Also, compatibility with scenario A was between 5–6, whereas scenario B was between 2–3. Participant P9 explained that for them, an environment that was as natural as possible seemed to be the most interesting and suitable for their personality. Several responded similarly, e.g. P3 when describing Scenario B in VR: “although there was a lot of interesting things in this place, the scenery was depressing”. P1 did not feel a connection to a place like presented in scenario B, but mentioned that seeing many wind turbines in the same place would be an experience itself. They could visit the place, but would not like to spend long periods of time there. More detailed differences of the perceived restoration can be seen in Fig. 6. For example, in coherence, there is a noticeable dispersion in the 2D version of scenario B. Some of the participants mentioned that confusion, distraction, or chaos is not always a negative thing. That might partly explain the split in the responses.

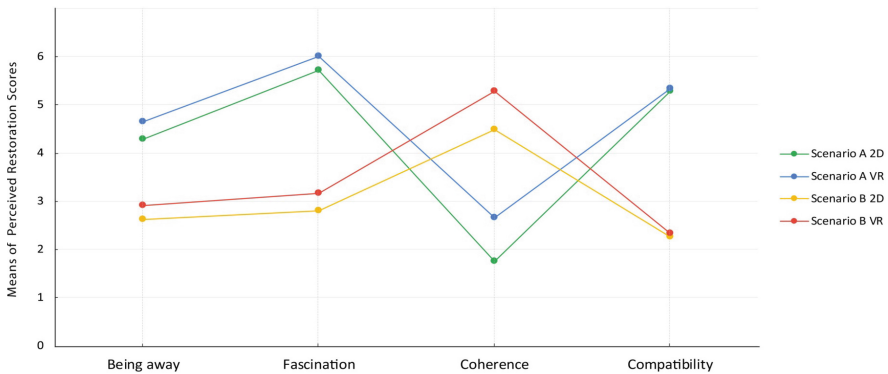


Fig. 5. Means of perceived restoration divided by four categories in both scenarios with VR and 2D ($n = 14$)

4.2 Green Energy and Sustainability

Scenario B who’s landscape was dominated by wind turbines, aroused mixed feelings in the viewers. Sustainability issues came to mind for many and both pros and cons were shared in the answers. More on the positive side of opinions the progress in the use of wind power was seen as a good thing. Also, huge wind turbines were mentioned to arouse interest or curiosity, e.g. “The landscape and the view are new. I have never been near wind turbines built so close together. A confusing, but at the same time curious state of being” (P10). On the other hand, the built environment was also stated to be more boring compared to nature.

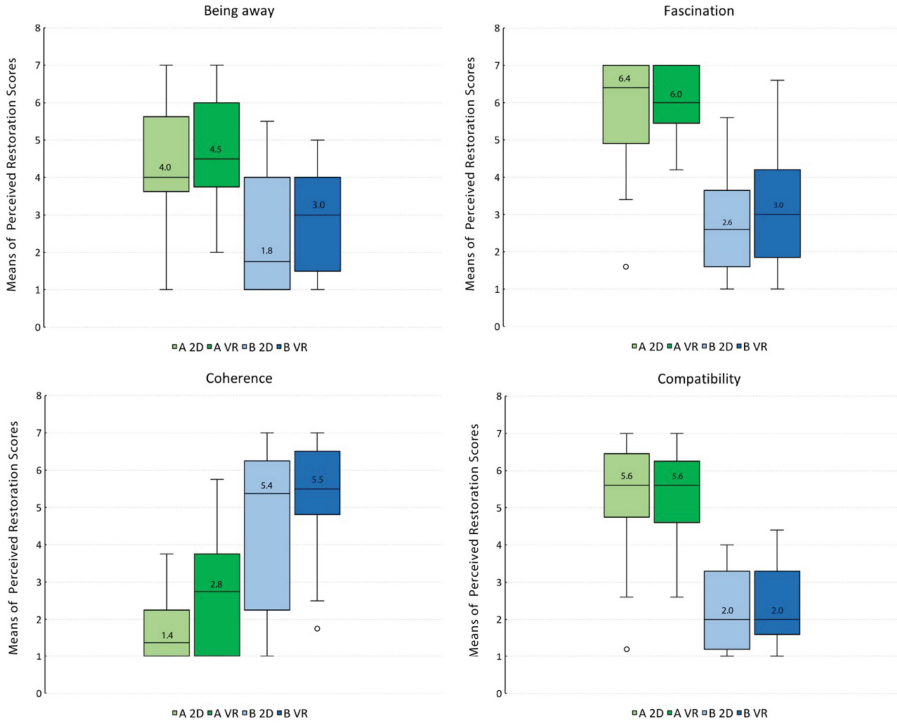


Fig. 6. Boxplot of perceived restoration divided by four categories in both scenarios with VR and 2D (n = 14)

On the negative side, the abundance and proximity of wind turbines were said to spoil the nature experience, e.g. “Wind turbines spoil the landscape. You wonder what kind of noise the turbines make if you walk among them” (P14). However, it was not seen to affect the fascination with the place itself since large-scale mechanical things can be as fascinating to watch as nature, e.g. “Wind turbines could also be fascinating objects, mainly to look at and wonder. Technology is also interesting along with nature” (P6).

A more neutral viewpoint argued that wind turbines were a surprising element after scenario A. When viewed from a distance, wind turbines were a somewhat neutral sight. But in the foreground of the picture, they arouse the viewer’s desire to quickly pass by. The presence of wind turbines seemed somehow pervasive and disturbing. The presence of strange wind turbines was said to give the place a cursed impression which confused the viewer. Visiting there might be interesting but wind turbines were seen as somehow threatening as if they could attack you, e.g., “a dystopian landscape where I just want to cut down the wind turbines” (P12).

It was also mentioned that in scenario B human influence on the landscape was clearly present which made the place feel not as mentally relaxing as in

scenario A. Especially when there was another picture as a point of comparison, the difference was clear and the negative feelings were quite strong, e.g. “Wind turbines make you irritated and the landscape somehow remains empty” (P13). One participant described nature as a place where there are no worries and you need to have respect towards it.

4.3 Immersive VR Versus 2D Printouts

After the study session, each participant was asked which testing method they liked better. Everyone answered they preferred VR as a testing method over the 2D image. Still, a few of the respondents answered that the image printed on paper helped them to imagine themselves to the scene better. With the paper version, it was perceived that there was more flexibility to explore your own reflections and feelings towards the setting, and it left more room for imagination, whereas the VR could be overwhelming with its all confusing elements. Interestingly, VR environment could also be perceived as psychologically distancing, since everything was already given and you needed to observe the scenery as a floating outsider.

Some participants who tested VR first felt uninterested in watching the scenarios again in 2D after they had already seen it in VR. They stated that looking at the image they were not as observant as in VR. It was not possible to enter the picture and the landscape in the same way, which they felt limited their experience. Even if the picture was still beautiful, it remained uninteresting compared to VR: “After seeing the scenarios in VR, I don’t really care about the image” (P7). The 2D image looked nice, but it did not make as strong impression as VR “It’s hard to get anything out of the picture alone after wearing VR glasses” (P3).

The VR experience was perceived to be more forgiving of the inconsistencies in the AI design. Respondents said they paid less attention to little details when there was more to explore. In VR the virtuality of the environment felt less disruptive than on paper. This could be explained that virtuality feels more natural in Virtual Reality as it is automatically part of it. Virtuality in this case referring to the artificial nature of the environment. Vague unfinished AI structures were not visible on a printout. It helped participants to focus better, and some felt more active while looking at the paper image than in the VR world. The 2D picture was mentioned being more “cozy” than VR environment. It was easy for many to imagine the sounds in the scenery through the 2D image, e.g. water and birds in scenario A and the loud noise of wind turbines in scenario B.

The evaluation of the positive and negative feelings evoked by the scenarios produced conflicting answers. For example, P1 felt that the experience of scenery B was more positive in 2D than in VR. Whereas, P3 was surprised how negative feelings were also transmitted through just a picture.

4.4 VR Experience

On average, participants felt that VR as a testing method was interesting. It was mentioned that virtual nature was an interesting way to reflect on one's own nature experience. Comparing the same landscape in the picture and in VR brought up new perspectives. It made participants curious about the environment and feel like they were not in a small room. A positive feature of the VR world was being able to look everywhere around you which made the experience feel more authentic, e.g. "When working with VR glasses, you feel that you are somehow in control and the feeling is more authentic. Feels easier to belong to that place" (P13). One participant questioned the need for VR in this kind of test, e.g. "There wasn't anything to do in VR so I was wondering a bit if the VR aspect was necessary, but I was interested enough to look around the environment" (P7). Several participants mentioned that it would have been interesting to be able to move around in the VR environment, exploring the surroundings and interacting with it. One participant suggested that lying down and looking at the scenery could have been one option as well. P11 explained that her experience in VR helped her to get a general idea of the place, but at the same time she felt that she was mainly a spectator and did not feel like she could participate in the scenery.

Compared to other possible alternatives, VR was said to be the best method for this kind of use. Participants mentioned that VR helped them to imagine themselves in the setting. The 3D world and the relative scale of the objects around them were easier to understand in VR.

One factor that should be considered is the soundscape. During the experiment window was open and bird song could be heard from the outside. Some participants mentioned that fitting to the experience. During the testing, it started raining outside and the window was closed. Instead of the bird sounds, one participant heard the mechanical sound of ventilation and it seemed to affect her experience, e.g. "I feel like I hear a technical sound coming from the wind turbines. I wonder how low the wind turbines are" (P19).

Since several participants had used VR a lot, they were critical of the quality of the VR experience, e.g. "With VR, the user gets a good spatial experience, as long as the environment looks believable and not distorted" (P5). Poor quality, a fish-eye effect, and strange AI-generated elements disrupted the overall experience. Some participants also mentioned feeling dizzy or uncomfortable because of the distortion, e.g. "There were a lot of flaws in the place that broke the experience. The landscapes were disconnected from each other and were connected illogically" (P14). Seeing your body instead of hovering in the air was mentioned as one method to improve the experience.

4.5 AI-Generated Environment

Many participants were like-minded about scenario A being fitting for outdoor activities such as hiking or camping. However, it did not resemble the local landscape, making it more difficult to feel a deep connection to the place. The

unbalanced mixture of landscape elements and vegetation not found in the region made people wonder where they were. P10 described her experience in scenario B: “I must be at the seaside because the vegetation does not look like the vegetation of the fells. There is a strong wind there”. She made reasonable deductions based on what she saw, even though it might contradict the previous mountainous and forested environment.

Several participants felt that the environment was confusing because of the inconsistencies in the AI environment, such as rivers that disappeared and appeared in strange places, or branches hanging from the air. The AI’s weird design made it obvious that they were in the VR world. However, as participants were able to place themselves in the picture as if they were in real nature, the experience was more comprehensive. Some participants explained that they could imagine elements of real nature there, such as the sound of water and real changes in height. Some participants were impressed the how realistic the picture was. If you glanced at it fast it looked like a photograph, one participant described their first impression.

The AI-generated virtual environment made some of the participants cautious or skeptical. The virtual environment was exaggeratedly AI-like when viewed with VR glasses. The inconsistencies in the images noticed by participants (Fig. 7) and the variation in image quality disturbed the experience and moved the focus from the actual nature experience more toward other elements. One participant said that its unauthentic nature made them approach it with a certain reservation. It even felt a little annoying for them and they stated that they would rather choose “real” nature. Virtuality of the nature environment could affect participants’ perception of it. For example, P8 described their experience: “The fact that the landscape is virtual takes away the strongest edge from negative feelings. At the same time, the picture reminds us that this is a reality somewhere. Beautiful nature is being destroyed and we are all collectively guilty of it because of our energy needs”.

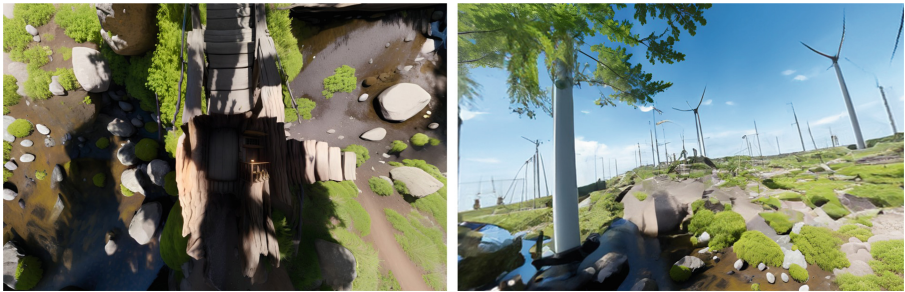


Fig. 7. Strange details in VR world generated by AI: a window on the bridge (left), half-finished wind turbines, and strange structures on the horizon (right)

5 Discussion

5.1 About the Methods VR vs 2D Printouts

The main focus of our research was to compare the methods of using VR and paper for studies concerning nature landscapes. Generally, VR versions of the scenarios were perceived as slightly more positive and less negative than the 2D version in both scales. VR was generally liked by the participants, and it was perceived as immersive and interesting. For instance, some participants who tested the VR first felt uninterested in watching the scenarios in 2D after they had already seen them in VR. Thus, we believe that the immersive and experiential power of VR can be utilized to capture people's attention to topics related to natural landscapes and technology. However, the unauthentic nature generated by AI should be carefully checked for inconsistencies.

Interestingly, the paper version was said to provide more flexibility to explore your feelings towards the setting, leaving more room for imagination. Prior research on using VR for user studies has reported that in VR, users' attention is easily captured by high-fidelity details [25]. This may be true also in our study. These findings highlight that paper illustrations and simple low-fi solutions can have their place when engaging citizens in discussions about technology and nature. We believe these methodological findings provide valuable insight when planning future studies addressing nature experiences.

5.2 About the Just Green Transition

Our research contributes to the topical discussion of just transition for green technologies [41]. Our research touches on the complex interplay between technological interventions and the preservation of genuine nature experiences. Sustainable technologies and their development are critical given the climate change crisis. However, creating and using technology that promotes environmental sustainability and reduces the ecological footprint creates conflicting responses. Some of the affected people are those who live in the areas that are subject to the implementation of large energy plants or mines. These are often remote areas, such as subarctic regions with indigenous people and their traditional lifestyle [30], and high recreational nature value for tourism. The transition to sustainable technologies already creates conflicts and societal tensions [6].

Behaviors related to eco-friendly and sustainable technological solutions are promoted as a green transition. On the other hand, locating windmills in wilderness areas is criticized for ruining the wilderness, harming the natural ecosystems including traditional occupations such as reindeer herding, and generally negatively affecting the nature experience. Our explorative study results are aligned with this, as the nature landscape without windmills was perceived more positively through the Positive and negative Affect Schedule (PANAS), the qualitative responses seconding this. Our findings suggest that immersive technologies like VR can be valuable tools for environmental impact assessments and stakeholder engagement, offering a more nuanced and richer understanding of public perceptions and acceptance of renewable energy projects.

5.3 Limitations

We acknowledge that our study is limited by the small sample size and not balancing the presentation order of the A-B scenarios in the study. However, the main focus of our research was on exploring and evaluating the methodology of using VR for assessing nature landscapes and comparing it to paper-based presentations. Also, we noticed that repetitive questions and the use of the same pictures seemed to affect participants' perception of the virtual environment to some extent. As another limitation, the quality and realism of the AI-generated VR environments impacted participants' perceptions, including difference between the scenarios. This is however a methodological lesson learnt in preparing the visualizations. For instance, we cannot be sure whether people did not like the wind turbines or the lack of trees. Future research should focus on improving the realism and consistency of VR environments to better assess their impact.

In the future, to gain more insight into the phenomenon of perceptions of technology in nature, a comparison with a data set collected in-the-wild in the nature should be included. This is especially important, as there is generally a lack of nature and technology user experience studies that have been conducted in a wilderness context. Jones et al. report that of 101 HCI studies conducted outdoors involving a person using a computer, 82 took place in urban settings [15]. Including an in-the-wild study would also provide insight into the methodological feasibility of simulating the nature experience in VR.

6 Conclusion

Our research seeks to make two types of contributions. On one hand, it offers insight into user perceptions of integrating technology into nature scenes. On the other hand, it emphasizes the importance of creating research methods for assessing technologies that seek to create close-to-genuine nature experiences or simulate and study the disturbances in nature experiences in VR.

Comparing VR and 2D paper printouts revealed that VR was perceived as an immersive, interesting, and even exciting experience, which participants liked and which they perceived suitable to assess nature scenarios and technology embedded into it. However, 2D paper printouts were reported as giving more room for participants' imagination and reflections. The VR environment also led participants to pay attention to other details rather than the holistic landscape. Our findings comparing the landscape without and with windmills reveal that the landscape without technology was perceived more positively and as more restorative. We acknowledge that our findings are limited by the small study sample and the artificially generated content used.

Acknowledgements. This research has been supported by the project Reconceptualizing Boundaries Together Towards Resilient and Just Arctic Future(s) (REBOUND), grant number 358482 and 358498, funded by the Strategic Research Council (SRC) established within the Research Council of Finland, and ProtoXR project funded by ERDF.

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