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# While Experiencing a Forest Trail, Variation in Landscape Is Just as Important as Content: A Virtual Reality Experiment of Cross-Country Skiing in Estonia

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**Abstract:** It has long been understood that diversity is a key aspect of what makes a landscape attractive but to what degree of diversity and how is it experienced? Many forest landscapes are generally monotonous in character or are broken up by forest management activities such as clear cutting, which may negatively impact their potential for recreation and psychological well-being benefits. We conducted a virtual reality experiment where people were taken on a trip along a simulated cross country skiing track in an Estonian forest. Participants followed a route at simulated speeds typical of cross-country skiing. The route was long enough to experience several minutes passing through one type of forest landscape with a series of small variations in character followed by several minutes passing through a notably different forest landscape. The restorative experience obtained by the visit was measured periodically in each version of the landscape. Univariate general linear modelling analysis was statistically significant ($r^2 = 0.651$, $F(198, 965) = 9.108$, $p < 0.001$) and showed that while respondents preferred less-dense forest in general ($B = 0.189$, $p = 0.001$)—an expected result—a comparable amount of positive restorative response could also be attributed to prominent changes in forest character, regardless of the type of forest ($B = 0.401$, $p < 0.001$). We hypothesise that respondents were reacting favourably to sudden changes in forest appearance after prolonged exposure to one forest type—that diversity is important in maintaining interest, reducing boredom, and in providing a restorative experience. The implications are, firstly, that a virtual experience can detect restorative effects and, secondly, that recreational trails should be designed to pass through varied landscapes offering continually changing diverse experiences—the impact of which can be tested in the virtual setting because there is control of all variables.

**Keywords:** landscape perception; restorative experience; landscape simulation; locomotion; variation

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## 1. Introduction

The health and well-being promoting properties of forests have received increasing attention. The Japanese practice of "Shinrin yoku" or "forest bathing" has been introduced around the world, while many aspects of contact with nature have been shown to be beneficial for physical and mental wellbeing [1]. This exposure is mainly undertaken as a recreational experience, through hiking and cycling in summer or, in northern latitudes, via cross country skiing in winter. Numerous studies have shown that people prefer landscapes that resemble savannahs or parks, where large trees are scattered across a smoothly textured ground surface [2,3]. The defined depth of view that allows visual access to further parts in the landscape is another property that increases preference [2,3]. From the perspective of cognition [3], people tend to like landscapes that are interesting to explore, but also easy to understand at the same time. Conversely, overly complex views or featureless, uninteresting scenes, limited depth of view, and low locomotive permeability are known to cause low preference [2,3].

*1.1. Preferences for Forest Landscapes*

Similar findings have also been confirmed in studies dealing specifically with forest landscape views. For example, a review of 53 studies in Nordic countries on forest landscape preferences [4] found that people prefer older forests with larger trees (close to the harvesting age). A Europe-wide study [5] showed similar results while another study conducted in Poland [6] showed that older, multi-layered, and species-rich forests where trees are naturally located, instead of in planted rows, are preferred for recreation. The same studies found that people do not like large clearings and visible traces of logging activities [4–6]. In the case of older forests, there is an obvious need to find solutions to avoid or mitigate the conflict between recreational use and forest management interests [7].

The species composition of forests, including understory vegetation located at eye level, and forest management techniques, also affect the visual and locomotive permeability of forests. Several studies state that physical accessibility and especially an open or semi-open view increases the preference and recreational value of forests [4,8–11]. Herzog and Kropscott [12] found that the existence of landmarks and visual access to be positive predictors of legibility and, in turn, coherence and legibility, that facilitate ease of understanding [3], affecting preference positively. In the specific case of views along forest paths, Herzog and Kirk [13] found visibility through vegetation in the vicinity of the path and visual access to all parts of the setting to increase preference. A later study by Herzog and Bryce [14] clarified further that visual access was positively correlated with preference in denser forests, while in sparser forest stands the preference correlated positively with mystery.

A specialisation within landscape architecture is that of forest landscape design. Here, instead of following standard forest management practices such as regular clear cutting which results in unnatural geometric shapes, more organic, naturalistic shapes are designed, and trees are left on sites to provide variety. Little formal research has been conducted in this area but the practice is well-established [15].

*1.2. Benefits of Variation*

It has been suggested that the preference for novelty and variety may be a basic psychological need [16,17]. Behaviour research on physical activity and exercise suggest that variety may promote activity levels and thus health benefits. A larger variety of exercise equipment has been shown to increase participation in exercise activity and enjoyment [18]. Variety in the activity itself may also be conducive towards more engaged and active participation. Perceived variety of the task or exercise activity has been shown to affect frequency of exercising and motivation to be physically active positively [19,20]. Furthermore, perceived variety in exercise at a young age may positively affect long term adolescent moderate exercise behaviour [21]. Most remarkable is a case where respondents preferred variety over the most favourite activity. Raynor et al. [22] demonstrated, in an experiment with exergaming, that variety in the content provided by four different exergames over the period of 60 min helped sustain activity at the same level, while activity levels dropped markedly if the same amount of time was spent only in the participant's most favourite exergame.

Among the literature on landscapes in general and forest landscapes in particular, the evidence base for variation is less pronounced. Diversity is postulated as one of the key aspects (together with unity and spirit of place) that are present in landscapes considered to be attractive [23]. Complexity is also one of the cognitive variables, together with coherence, legibility, and mystery, predicting preference according to the work of the Kaplans [3]. Some studies suggest planning forest trails to pass through vegetation with a different appearance and changing view range, promoting visual variation [9,10]. Axelsson-Lindgren and Sorte [24] underlined the benefits of visual variation in recreational forest design and concluded that a path through a forest with more vegetation types was found to be more pleasant and suitable for more recreational activities. The sequencing order or combination of different settings may be equally important besides structural properties within a single landscape unit. Designing forest tracks only in the settings with the highest preference scores may therefore be a weak strategy as people would miss out on the benefits of variation in the forest experience.

### 1.3. Measuring Restorative Value

Research on landscape preference can use a variety of more specific constructs, such as scenic beauty, aesthetic preference, or restorative effects. Attention Restoration Theory [25] is one of the key theories connecting exposure to nature with improved mental wellbeing (the other is the Stress Reduction Theory [26] (see below). Both of these may play a role in the mental health benefits obtained from forest recreational experiences. Research has shown that preference and restoration, although each discernible and specific constructs [27], tend to correlate strongly, and that restorative value may serve as the starting point for formation of preference [28–30]. Therefore, the design of recreational areas should focus specifically on increasing the restoration potential. There are several self-report survey scales for measuring restoration [31]. The Perceived Restorativeness Scale (PRS) [32] and its various derivatives are based on four of the dimensions of Attention Restoration Theory (being away, fascination, extent, and compatibility). Another, the Short-version Revised Restoration Scale (SRRS) [33], combines Attention Restoration Theory and Ulrich's [26] Stress Reduction Theory, and is suited well [31] to measuring perceived change in restoration. It is based on four dimensions of emotional, physiological, cognitive, and behavioural responses, each measured with two questions. The SRRS tackles restoration more broadly, not only from an attention fatigue perspective, and is a fairly short instrument, aiding administration of the survey in time-limited conditions or out in the field.

### 1.4. Stimuli in Landscape Preference Research

Use of still images as substitutes for the real environment has long been considered a valid method in landscape preference research. For the purpose of validity of the representation, it is advisable to use multiple views and wide-angle panoramas [34,35]. However, following Gibson's [36] ecological theory of visual perception, Heft and Nasar [37] argue that since landscape is more often perceived when moving through it, studies should employ dynamic visual representations (e.g., video). They advise caution when drawing far-reaching conclusions based on studies that only use static scenes. MacBride-Stewart [38] makes the argument that active engagement with the landscape, the emotional and aesthetic interaction between person and environment, is important for understanding the health benefits of landscape. According to her, recreational landscape is not merely a natural resource that could be mapped and exploited, but a setting where people interact with their surroundings through activities and emotions with motivation for exploration and adventure.

Many studies of forest landscape preference or restoration have also used static imagery, for example [4,6,8,9], showing a scene for a relatively short period of time compared with the amount of time experienced when moving along a real hiking trail. Rapidly changing static images may not cause the same response in people as moving around the same environment for a longer period of time. The most immediate assessment can be obtained by actually moving through the landscape instead of viewing photographs. Examples of research on similar topics in people physically present in the forest landscape [10] or studies where preferences are investigated retrospectively after a visit [11] are found less often. Conducting such studies requires more resources and there is no easy control over all the visual parameters that are part of test variables.

Photographs and videos of real landscapes allow preferences in relation to the specific scenes to be identified but so many variables can be present over which there can be no or little control, that it can be difficult to draw statistically valid conclusions. Thus, a number of studies have tested comparisons of images which have been manipulated using image editing software. This is more difficult in the case of videos but it is possible to create realistic sequences of, for example, travelling along a road where the entire landscape has been created using computer software. In a study of the preferences for roadside landscapes in Latvia, Vugule et al. [39] employed realistic but artificially created videos to show respondents the same stretch of road with different types of landscape in order to elicit an understanding of preferences. While not projecting such videos in a way that created a virtual reality experience, they came close to allowing people to feel that they experienced the landscape in a quasi-realistic way, at the normal speed of driving and with a wide field of vision. Similarly, Vassiljev et al. [40] used videos from computer generated simulations of exploratory movement through sections of a coastal landscape to test the acceptability of different recreational structures proposed to be installed there. Expanding further on the issue of movement in landscape, preference may change over time as people become used to the scenery. Viewing an image for a minute may reveal a certain preference or restorative score while exploring the landscape for several minutes could yield different results simply because of habituation.

There is also an emerging field of using artificially created landscapes, within a Virtual Reality (VR) environment as a surrogate for experiencing real landscapes—perhaps for people unable to access the outdoors for some reason, such as infirmity. The technology of gaming and the power of computer graphics enable increasingly realistic scenes to be created (see the example of the roadside landscape above) which can be experienced via large curved screens, on multiple TV screens or via VR headsets. The potential therapeutic value of this has been explored within the EU Horizon2020 Project BlueHealth [41]. Thus, there is the potential to use VR technology dually, to provide restorative experiences and to test both preferences and, e.g., restorativeness, in realistic environments where the landscape parameters can be controlled to avoid confounding variables and where an immersive and mobile experience can be achieved.

### *1.5. Skiing*

As noted earlier, providing recreational opportunities in nature, including forest landscapes, is an important goal of health promotion. Cross-country skiing in forest landscapes in northern latitudes is a popular form of healthy sport in the winter time. Skiing provides excellent physical exercise and an opportunity to feel close to nature and to move easily through the landscape, usually along pre-existing and sometimes groomed trails. While some skiers look for serious exercise and want challenging routes, others prefer to take things more gently and to use the opportunity to enjoy the scenery. At the same time, many forests are also managed for timber production, and there may be conflicts between these two interests, especially where the management techniques involve extensive clear cutting—removing all the trees from a patch several hectares in area, apart from some scattered trees left to provide seed or bird perching. In order to offer good design solutions, that potentially mitigate the conflicts, it is necessary to know which spatial parameters of the forest landscape affect its recreational and restorative values.

An added challenge to identifying best design solutions is the impact of climate change on the skiing industry. Recent research on skiing and winter recreation in general has paid a lot of attention to the climate change impact on the activity [42]. It has been predicted that the impact on economies and communities could be substantial [43], the recreational value of the forest for the visitors could be affected considerably [44], and individual users are likely to show a variety of behavioural adaptation responses [45,46]. Many studies concentrate on downhill skiing where production and storage of artificial snow is easier to achieve. Cross country skiing usually takes place over a larger territory and poses additional challenges for adaptation. Landauer et al. [47] studied climate change impacts specifically on cross country skiing and point out that different groups of skiers in different cultural contexts may exhibit different adaptation behaviour. They argue, for example, that among Finnish skiers there would be difficulties in accepting increased fees stemming from the need for artificial snow production due to the current widespread availability of free cross country skiing opportunities in Finland, compared to Austria. Building on that work, Landauer et al. [48] propose an index to quantify cross country skiing vulnerability to climate change based on exposure, sensitivity, and adaptive capacity. A mapping tool [49] covering the whole of Finland, visualising the components of this index has been developed to help planners, the skiing community, and enterprises plan adaptation strategies.

One of the adaptations for cross country skiers would be seeking out new locations within the existing sites or seeking completely new destinations where snow conditions are better. For some visitors, place attachment may play a part in sustaining customer loyalty of ski resorts [50,51] so even if snow disappears, visitors might stay and adapt to other activities. Where the snow resource is becoming limited, skiers could be willing to make trade-offs on perceptional aspects of the landscape as long as some snow is available. In these circumstances, finding design principles that would support better recreational/restorative outcomes becomes important.

As noted above, conducting experiments in real landscapes presents several challenges, one of which is experimental control in finding locations where different variables can be tested in different combinations and where movement can also be incorporated. Skiers may travel at different speeds when compared with experiments based on hiking, and weather conditions may make the collection of data difficult if it is very cold, for example. Thus, the potential for using simulations as surrogates for testing real-world conditions is worth exploring further. As one of the relevant measures in relation to the health benefits of physical exercise is psychological restoration, it would be useful to know to what extent such restoration might be measurable and detectable in a simulated virtual reality situation. Further, the ability to test combinations of landscape variables under controlled conditions could have important benefits for forest managers working in locations where snow conditions remain good under different climate change scenarios and where, for example, forest management techniques to help to retain snow cover (maintaining dense shade), for example, could be tested for users' preferences.

### *1.6. Geographical Context of the Present Study*

Estonia is the subject of the present study, with the aim of examining the restorative potential of experiences while skiing through forested landscapes. Estonia, located in the hemi-boreal zone, is a well-forested country where over a half of the mainland is covered with mostly semi-natural yet managed forests. The forest cover in Estonia includes different mixes of deciduous (mainly *Betula*, *Alnus*, *Salix* spp.) and coniferous (mainly *Picea abies* and *Pinus sylvestris*) stands. All forests are freely accessible to everyone for recreation, including picking berries and mushrooms, regardless of ownership.

### *1.7. Aims and Objectives*

As forests are therefore central to most outdoor recreational experiences in Estonia, and as they generally retain snow longer in the season, they are also preferred by most skiers. Thus, gaining a better understanding of the preferences for and mental restoration potential of forests while skiing through different landscapes should add to our knowledge about how best to combine outdoor recreation with forest management. As noted above, carrying out preference research which includes movement through winter forests poses challenges. Although videos can be made using head-worn cameras, these present similar problems as for other videos where there is no control of landscape variables. In order to test different forest experiences such as forms and extent of clear cutting, a means of comparison is needed. Therefore, we decided to undertake a pilot survey to test the potential of the approach and to create a virtual forest in the 3-D landscape simulator, where the visual characteristics of the forest we are interested in are precisely controlled, and the simulated movement gives the opportunity to study:

1. whether a virtual reality environment can deliver a statistically detectable restorative experience and thus have potential to be a surrogate for real-life experiments;
2. and if so, whether there are effects emanating from the ordering of the visual stimuli or effects of habituation and boredom in the restorativeness scores given to landscapes

experienced as a longer continuous sequence, using a limited number of variables under experimental control.

## 2. Materials and Methods

We used a landscape simulator with a large cylindrical 160-degree panoramic screen to take participants on a virtual tour along a cross-country skiing track through a winter forest landscape, and measured their responses. Ethical approval for the study was obtained from Research Ethics Committee of the University of Tartu, approval code 369/T-16.

The simulator (Figure 1) had a screen measuring 2.1 m in height and a curvature radius of 3 m, a viewing angle of 160 degrees horizontally and 45.8 degrees vertically with a central axis pointing slightly downwards by 3.9 degrees. The space inside the curvature accommodated a maximum of 15 people at a time, allowing a life-sized immersive experience of virtual landscape that could be navigated freely by the operator. In this instance the researcher conducting the experiment kept the movement trajectory on the gently undulating simulated skiing track at the constant speed of 12 km/h without stops, always facing forward. The movement pattern contained only linear translation and did not simulate any jolts or swaying action that would be typical of actual walking or skiing (there is also a need to maintain a smooth movement because some participants in VR experiments can experience motion sickness). The viewing elevation was 1.6 m. Simulation did not include any sound.

**Figure 1.** View of the landscape simulator used in the experiment, giving a good idea of the dimensions and set up as it was experienced by survey respondents.

Each experiment session was deliberately long, lasting over 17 min, in order to correspond closer to an actual skiing trek and to be more in line with the reality of travel time. A longer duration was also necessary to allow plenty of time for filling out the survey forms. The forest character changed several times along the track and respondents' reactions were measured during every section change. Three different versions of the track were created, each having a different sequence of the forest sections. Different sequencing of the same forest sections allowed us to look into research question 2.

Responses were collected using the Short Revised Restorativeness Scale [33], translated into Estonian (Figure A1, Appendix A). The survey form consisted of four response dimensions represented by two questions each: cognitive response ("*I am interested in the presented scene*"; "*I feel attentive to the presented scene*"); behavioral response ("*I would like to visit here more often*"; "*I would like to stay here longer*"); negatively worded physiological response ("*My breathing is becoming faster*"; "*My hands are sweating*"); and emotional response on two bipolar emotion pairs ("*Grouchy/Good natured*"; "*Anxious/Relaxed*") [33]. All responses were expressed on a nine-point Likert scale, and based on these, a general score of restorativeness was calculated for each forest section. A separate page with the same eight questions was designated for each forest section in an A5 booklet given to each participant for them to complete.

As it was a pilot study, we chose to opt for convenience sampling. Students, colleagues and guests visiting the Chair of Landscape Architecture of the Estonian University of Life Sciences were invited to participate in the study. Adults without prior history of sensitivity to high contrast or flashing light (e.g., epilepsy) or balance disorders could participate in the study. No socio-demographical data was collected. A total of 194 participants undertook the study and submitted completed survey instruments.

### *2.1. Virtual Landscape Model Creation and Visualisation*

The simulated model was created with Blueberry3D software, version 2.5.20 (© 2007 Bionatics s.a.). We used raster land use and elevation maps (2.5 m pixel density) to generate a triangulated irregular network terrain surface automatically and populated it with 3D models of plants according to forest stand type definitions. Individual models of vegetation (trees, shrubs etc) in the stands were distributed automatically based on density and clustering parameters that could be defined within the software. In addition, a random 20% size variation and a random orientation of vegetation models was used to introduce additional variability. Models (3-dimensional) of tree species were created in the REALnat Premium (© 2007 Bionatics s.a.) program, version 1.0.53 and included representations of mature trees and various specimens of undergrowth and shrubs. Textures of the model of mature spruce trees were edited later to include snow accumulation on the thicker branches. We used a texture of snow, draped over the ground surface, to simulate snow cover. A flat elevation map was used for the terrain model, but small variations in micro topography were introduced to simulate smooth undulations of snow cover. A feature in Blueberry3D software that automatically places a road with given width and surface texture on the terrain and removes vegetation models from the path was used to generate the cross country skiing track in the forest. The authors verified the level of realism of the forest models within the parameters afforded by the software with the aid of reference photos and personal experience gained from cross country skiing tracks around Estonian forests.

The resulting landscape model was created in tiled portions at different levels of detail that could be switched automatically based on viewing distance to ensure the desired frame rate. During the experiment, the model was rendered in real-time using Vega Prime, version 2.2 (© 2007 MultiGen-Paradigm) visualisation software, which distributed rendering between three image generators, managed the frame rate, lighting, and atmospheric effects. We visualised the scene at 45 Hz frame rate with mid-day sunshine in March, with a few white clouds in blue skies; shadows of the trees were displayed at closer distances. A video processing hardware was used to blend images from three projectors into a single seamless panorama and warp the flat image to a curved screen.

### *2.2. Created Forest Sections and Related Data Variables*

We created two forest landscape types in snowy winter conditions typical to the hemiboreal zone: a fairly open, mature forest dominated by pine (*Pinus sylvestris*) (Figure 2a) and a visually much denser mixed forest dominated by spruce (*Picea abies*) (Figure 2b). Each had a groomed ski trail passing through, which was followed during the experiment to simulate the experience. The dichotomous variable "pineforest" was used to mark results associated with the two forest types. A third forest type, a more abstract pine forest without snow was used in the beginning of the experiment to introduce the level of realism of the simulation and to enable respondents to practice filling out the survey form (Figure A2, Appendix A). Figure 3 shows the major steps involved in the creation of the simulation.

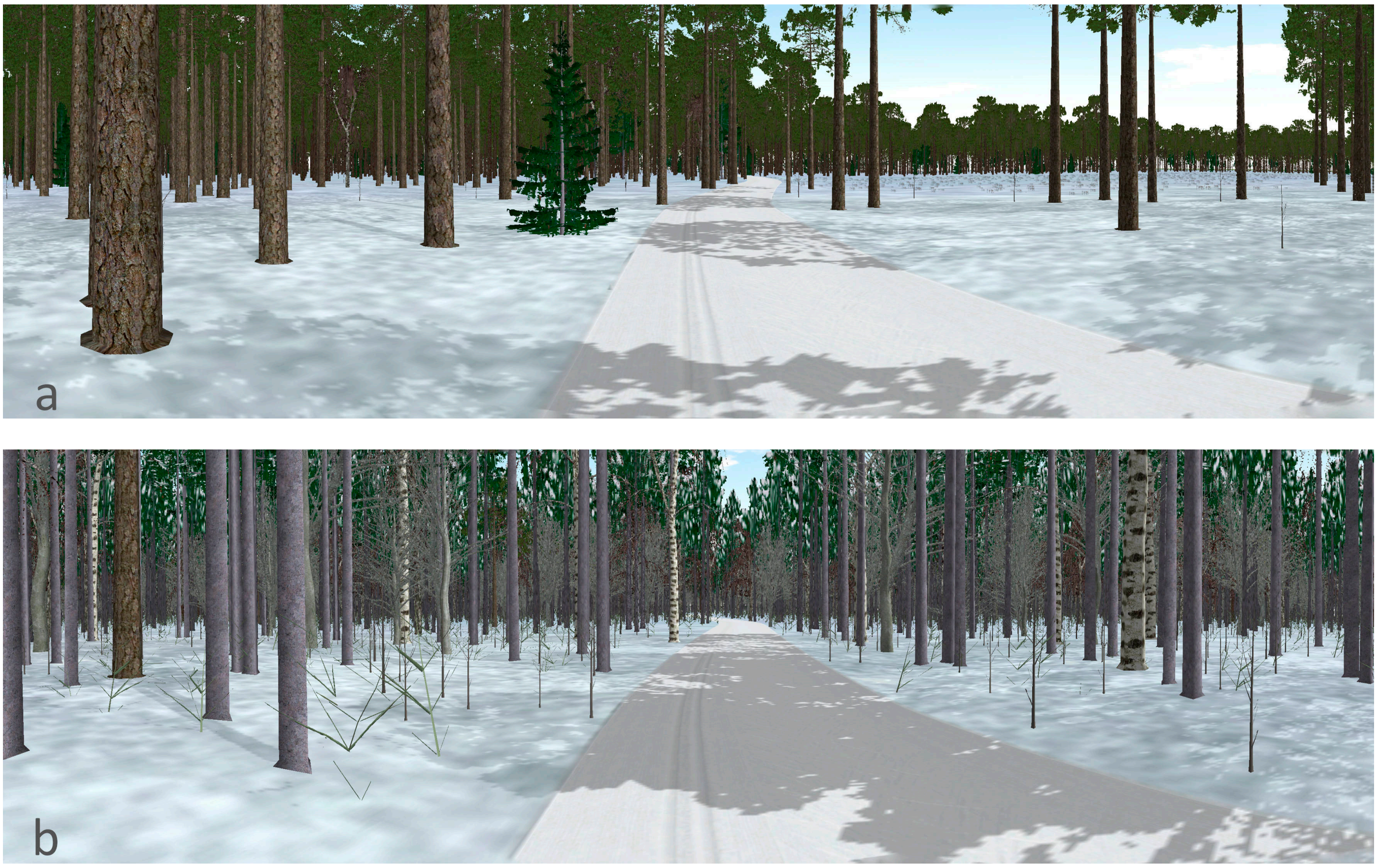


**Figure 2.** Examples of the two forest types: (**a**) being the open pine forest and (**b**) the spruce forest (see Figures A2–A8 in Appendix A for a full set of images depicting all seven forest models used in the study).

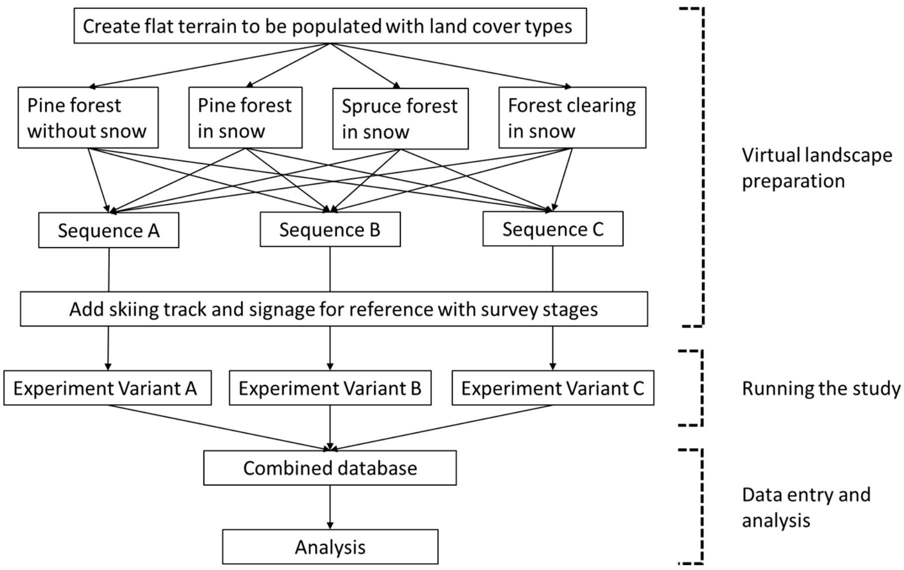


**Figure 3.** Flow chart of major steps involved in creation of the simulation and running the study.

Three forest management options were created and placed into three different mixed sequences (Figure 4) comprising variations on a forest without any felled area; a forest with three larger clear-felled areas measuring 80 by 160 metres each, placed with the shorter edge along the skiing track at 160 metre intervals; and a forest with six smaller clear-felled areas measuring 40 by 160 metres each, placed with the shorter edge along the track at 80 metre intervals. Two dichotomous variables "existence of few large clearings" and "existence of many small clearings" were used to encode these conditions in the data. Please refer to Figures A2–A8 in Appendix A for a full set of images depicting all seven forest models used in the study.

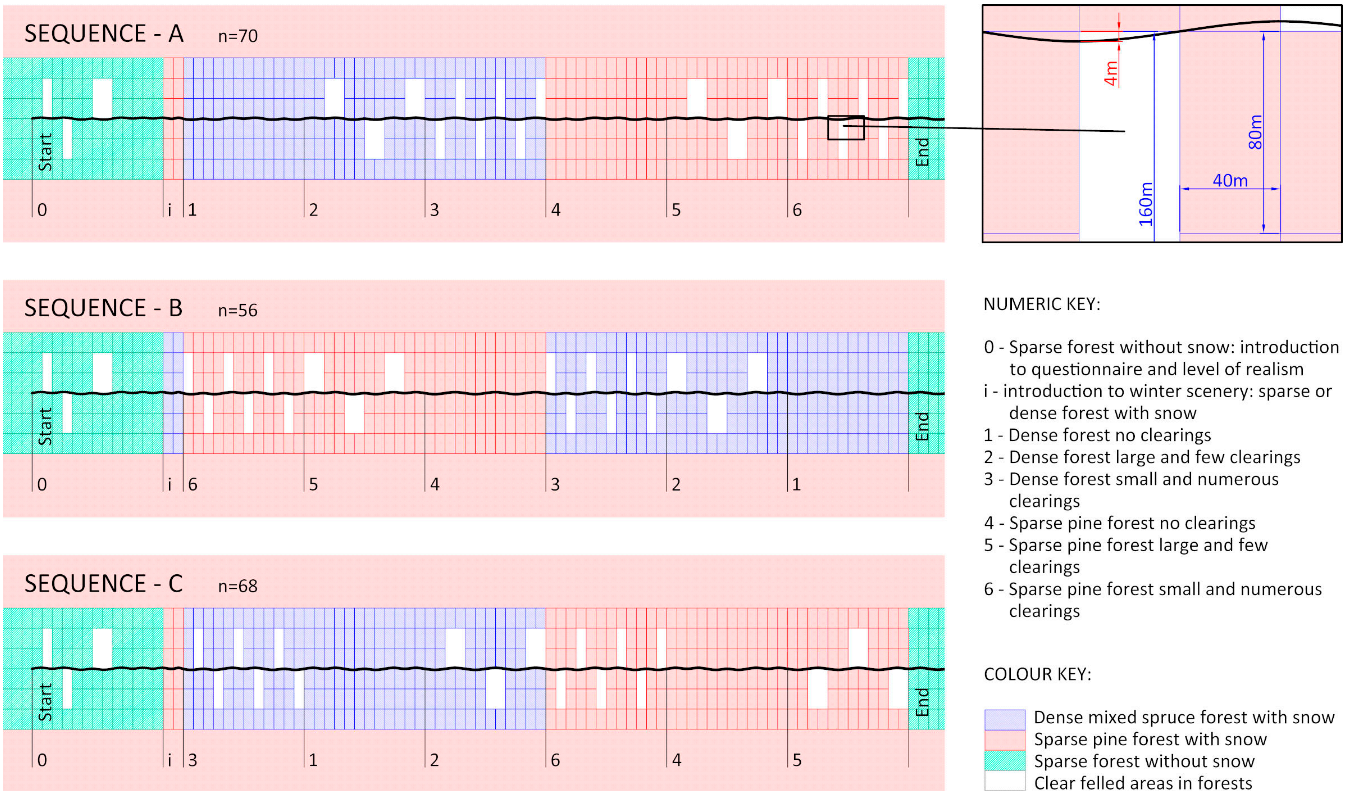


**Figure 4.** Schematic maps of the three sequences used in the experiment. Total number of participants that viewed the particular sequence is also shown.

Each forest section comprised 480 m with the first 160 m designated for viewing only and the latter 2/3 designated for filling out the survey form and viewing in parallel. The sections were sequenced to cycle through the three forest management variants within the same forest type. Thus, respondents were effectively traversing through 3 × 480 m = 1.44 km of either of the two forest types, followed by another equally long trek in the other forest type. The result of this arrangement was that there would also be two elements of monotony/boredom related to test administration and to stimuli. The repeated task of answering the same questions over and over while remaining seated was considered to generate a degree of boredom with the test and was coded in the data on an ordinal scale from 0 to 6 in ascending order.

Boredom associated with seeing the same forest type under various management conditions was considered to develop over time until a new, visually completely different, forest type appeared, bringing novelty to the experience. We included two occasions in our experiment to bear the characteristic of such novelty: firstly in the beginning of the experiment right after the introductory section of the experiment and secondly halfway through the experiment, where one forest type completely changes over to the other. A dichotomous variable "notable visual novelty" was used to denote the restorativeness scores that were collected in such conditions.

### 2.3. Analytical Methods

Survey forms on paper were checked for completeness, entered into a database, and validated. The personal restorativeness score for each of the seven sections of the forest was calculated based on the numeric responses to eight questions of the SRRS (values for physiological response were reversed by simple subtraction 10 − x; then, mean of all values was calculated). Appropriate variables were added to each record to represent the viewing sequence, forest type, forest management condition, boredom with test, and events of notable visual novelty. Resulting data file in csv format has been included in the Supplementary Materials. All data analyses were conducted in statistics software SPSS, version 19. First the inter-rater reliability analysis of responses was done, then basic descriptive statistics were calculated for each forest section and finally, a regression analysis was performed using univariate general linear modelling.

## 3. Results

Intraclass correlation analysis was conducted separately for the three viewing sequence groups to check for the consistency of the ratings given by the respondents before any further analysis. The results for average measures of reliability ranged between moderate to excellent with ICC (3,k) of 0.939, 95% CI [0.852, 0.988], $F(6, 414) = 16.489$, $p < 0.001$ for group A; ICC (3,k) of 0.865, 95% CI [0.670, 0.972], $F(6, 330) = 7.407$, $p < 0.001$ for group B and ICC (3,k) of 0.841, 95% CI [0.611, 0.967], $F(6, 402) = 6.277$, and $p < 0.001$ for group C.

Since the reliability analysis indicated that respondents were reacting consistently to varying visual stimuli, we proceeded to calculating mean restorativeness scores for each forest section in each viewing sequence and standard deviations of those responses (Table 1) for the overview and comparison. For each viewing sequence we also plotted the restorativeness scores as line graphs (Figure 5) in the same order as they had been viewed during the experiment to further illustrate the fluctuations of the score. Most evident in the results is the gradual decline in the scores, interrupted by a sudden spike present midway in all three graphs, suggesting a manifestation of boredom and novelty at interplay.

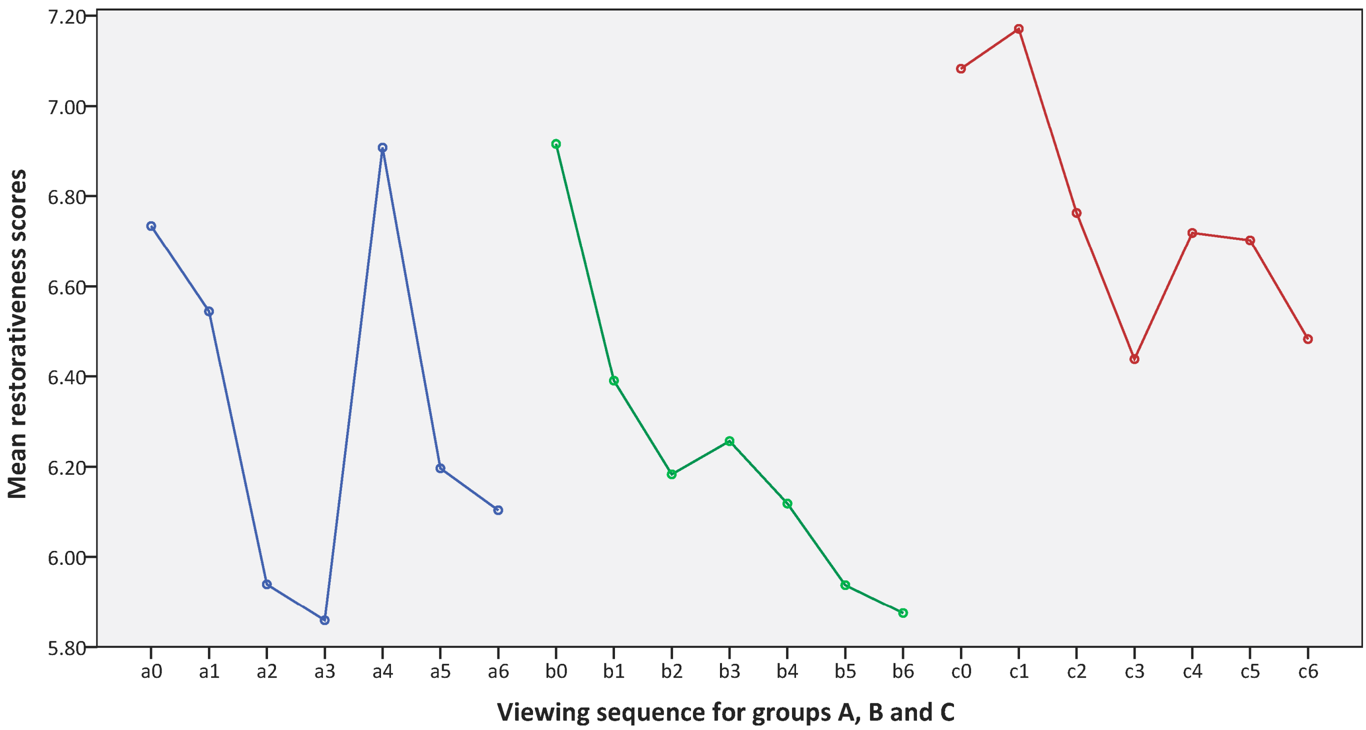


**Figure 5.** The variation in the scores for restorativeness along each section of each sequence, presented in the viewing order.

**Table 1.** Means and standard deviations for the restorativeness scores for each of the segments for each sequence. The numeric key used here is the same as in Figure 4. Results for sequences B and C presented not in the original viewing order, consult column "view order" for correct ordering.

| | | | Sequence A | | | Sequence B | | | Sequence C | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N = 70 | | | N = 56 | | | N = 68 | | |
| **Numeric Key** | **Forest Type** | **Clearings' Setting** | **View Order** | **Mean** | **Std. Dev.** | **View Order** | **Mean** | **Std. Dev.** | **View Order** | **Mean** | **Std. Dev.** |
| 0 | Introduction to survey form and realism | | a0 | 6.73 | 1.072 | b0 | 6.92 | 1.032 | c0 | 7.08 | 1.200 |
| 1 | Dense forest | no clearings | a1 | 6.54 | 1.283 | b6 | 5.88 | 1.499 | c2 | 6.76 | 1.440 |
| 2 | | large and few clearings | a2 | 5.94 | 1.128 | b5 | 5.94 | 1.354 | c3 | 6.44 | 1.347 |
| 3 | | small and numerous clearings | a3 | 5.86 | 1.243 | b4 | 6.12 | 1.433 | c1 | 7.17 | 1.129 |
| 4 | Sparse pine forest | no clearings | a4 | 6.91 | 1.293 | b3 | 6.26 | 1.169 | c5 | 6.70 | 1.414 |
| 5 | | large and few clearings | a5 | 6.20 | 1.178 | b2 | 6.18 | 1.125 | c6 | 6.48 | 1.429 |
| 6 | | small and numerous clearings | a6 | 6.10 | 1.248 | b1 | 6.39 | 1.206 | c4 | 6.72 | 1.347 |

The data was longitudinal in nature—the assessments of restorative value of seven landscapes given by respondents in sequence over a short time could not be considered independent of each other. Thus, instead of using a common multiple linear regression, univariate general linear modelling was used, with restorativeness treated as the dependent variable and respondents (with their id code) treated as fixed factors. The remaining time-variant predictors were included in the model as covariates.

We created five models that gradually ranged in complexity between landscape properties and manifestations of boredom (Table 2). The first two regressions establish if and how the landscape variables affected restorativeness scores. In both cases the pine forests were found to affect the restorativeness score positively. The inclusion of variables about clear cut areas in the forest increased the r squared value and indicated that both felling techniques negatively affected the restorativeness scores.

**Table 2.** Results of five regression models with main values in first column, followed by estimates of the constituent members and the effect size. The parameter estimates for 194 individual respondents are not shown; "ns" = not significant.

| **Nr** | **Regression Results** | **Parameter Estimates** | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | 95% C.I. | | | |
| | | **Parameter** | ***B*** | **Lower Bound** | **Upper Bound** | ***p*** | **Partial $\eta^2$** |
| 1 | $r^2 = 0.620$, $F(194, 969) = 8.144$, $p < 0.001$ | Intercept | 8.120 | 7.392 | 8.847 | $p < 0.001$ | 0.331 |
| | | pine forest | 0.136 | 0.032 | 0.240 | $p = 0.011$ | 0.007 |
| 2 | $r^2 = 0.630$, $F(196, 967) = 8.411$, $p < 0.001$ | Intercept | 8.278 | 7.556 | 8.999 | $p < 0.001$ | 0.344 |
| | | pine forest | 0.136 | 0.033 | 0.239 | $p = 0.010$ | 0.007 |
| | | few large clearings | −0.334 | −0.460 | −0.208 | $p < 0.001$ | 0.027 |
| | | many small clearings | −0.140 | −0.266 | −0.014 | $p = 0.030$ | 0.005 |
| 3 | $r^2 = 0.651$, $F(198, 965) = 9.108$, $p < 0.001$ | Intercept | 8.251 | 7.537 | 8.964 | $p < 0.001$ | 0.348 |
| | | pine forest | 0.189 | 0.080 | 0.299 | $p = 0.001$ | 0.012 |
| | | few large clearings | −0.172 | −0.303 | −0.041 | $p = 0.010$ | 0.007 |
| | | many small clearings | −0.260 | −0.388 | −0.132 | $p < 0.001$ | 0.016 |
| | | boredom with test | −0.042 | −0.078 | −0.007 | $p = 0.020$ | 0.006 |
| | | notable visual novelty | 0.401 | 0.259 | 0.542 | $p < 0.001$ | 0.031 |
| 4 | $r^2 = 0.641$, $F(195, 968) = 8.853$, $p < 0.001$ | Intercept | 8.125 | 7.407 | 8.843 | $p < 0.001$ | 0.337 |
| | | boredom with test | −0.020 | −0.053 | 0.012 | $p = 0.224$, ns | 0.002 |
| | | notable visual novelty | 0.400 | 0.282 | 0.518 | $p < 0.001$ | 0.044 |
| 5 | $r^2 = 0.640$, $F(194, 969) = 8.887$, $p < 0.001$ | Intercept | 8.044 | 7.338 | 8.751 | $p < 0.001$ | 0.340 |
| | | notable visual novelty | 0.430 | 0.323 | 0.538 | $p < 0.001$ | 0.060 |

Time varying variables relating to boredom were included in the third model and yielded the strongest values for the regression. In this model, the pine forest and notable visual novelty (created by the change in forest type) both positively affected the restorativeness scores (model 3 in Table 2). Judging by the values of *B* and partial $\eta^2$, it is actually the notable visual novelty that influenced the outcomes more strongly than the sparser pine forest type. Both of the clear-cut felling techniques and general boredom with the test (caused by considerable test time and repetition of the same questions) affected the results negatively. Here, judging by the values of *B* and partial $\eta^2$, the boredom with the test had the weakest impact.

Finally, it was checked to see if the variables related to boredom alone could be used to predict the outcome. In the 4th model, boredom with the test had non-significant results. The last model included only the notable visual novelty as the covariate and it significantly positively affected the restorativeness scores. The *r*-square of that model was larger than the first two models which included landscape variables as covariates.

## 4. Discussion

Judging by the standard deviation of the scores and the rather small partial eta-squared values it is obvious that the majority of variability in the data comes from individual respondents. Nevertheless, meaningful generalisations about the properties of the forest landscape and the time related factors affecting the restorative value can be made.

Firstly, to answer research question 1, it was possible to detect statistically significant restorativeness by using the VR simulation of the landscape, and that this varied according to forest type and the character of the forest along the simulated routes. We found that visually sparser pine forests show better restorativeness scores overall. This compares with other studies [4,8–11,13] which have shown that such forests are one of the most preferred types. The design of our experiment does not allow us to attribute the higher scores of pine forests to a particular psychological mechanism: it could be a cultural manifestation, but it can also be related to visual permeability as noted in other studies [4,8–11]. The lack of foliage on the deciduous component of forests in winter conditions greatly improves their visual permeability, including that of the denser spruce dominated mixed forests. Visibility is now mainly affected by density of the trunks of the trees and stems of the understory. Conversely, white snow cover with an even surface creates a smooth background that might accentuate the grey trunks and stems. So far, we can see some similarity in results with those from other studies, including those conducted using photographs [4,6,8,9], supporting our contention in research question 1 that a VR simulation can function as an experimental surrogate for a real experience. In the case of movement, since the micro-scene changes very quickly, views change from being potentially blocked one second to open and visible another, so that overall permeability may be judged as greater while moving—something to test further. This feature also strengthens the value of undertaking studies where movement is simulated so that these nuances can be identified and taken into account in management, for example in ensuring a certain density of trees.

Secondly, the forest management practice of regularly shaped clear-cut plots was associated with a decrease in restorativeness scores. In the model with only forest landscape related covariates, larger but fewer clearings gave stronger negative effect. On the other hand, the model that also took boredom related variables into account, had the opposite results—it was the smaller, but more numerous, clearings which had the stronger negative effect. Both types of clearing strategies (with sharp straight edges) had a negative impact on responses, which is in agreement with previous research [4–6]. While research into forest landscape design is relatively sparse, as noted above, the actual forest design in practice is well-established in some countries [15]. This result identified the potential for developing management practices that seek to improve the visual appearance by trying to blend such openings into the forest landscape. It is worth noting that the simulation did not show stumps, heaps of branches, deep wheel tracks left by forest harvesting equipment, or any other signs of commercial felling activity—which would have been partially buried beneath the snow in any case. So in real-life-conditions if snow was sparser and less deep, these visual disruptions known to reduce the attractiveness of the forest [4–6] could be more pronounced and the impact would probably be even stronger.

However, the current experiment was set up to induce boredom by placing forests of the same type consecutively. In addition, the significant visual novelty positively affected the outcomes. Further research could include felled areas with more significant visually intrusive elements introduced along the ski tracks adding notable visual novelty. Perhaps after spending a longer time in forests without felled areas, a patch of different types of forest with some clearings would have the same visual novelty impact. With regard to this experiment, where movement through the forest was relatively fast, the rate of change in the scene is also affected by the degree to which an observer can assimilate visual stimuli. In studies along roadsides this effect is more pronounced [39], yet the rate of change and ability to pay attention to detail might be affected when compared with walking. The ability to stop and look at an interesting detail in the scene is less easy when skiing compared with walking, so it may also be that larger changes or diversity at a meso- or macro- scale are more easily registered.

Third, the impact of the boredom with the test (caused by repetition of the questions of the survey instrument and considerable duration spent in forest landscape) was rather small. This, in turn, suggests that state boredom was probably not affected strongly and that it might not be appreciably detectable with the psychometric tools. Future experiments that wish to monitor state boredom changes may need to include even more complex arrangements of landscape elements.

The most profound finding of this study was the strong positive impact of visual novelty on the restorativeness scores. In the regression that included both landscape and boredom related variables, it was visual novelty that had the largest B and partial eta squared values. Also, the model that took only visual novelty as the covariate outperformed the predictive capacity of the model that took only forest variables into account. This finding suggests, that variation in the landscape is just as important as the "preferred" or "popular" forest type, at least in the context of restorative experiences of skiing. While designing recreational facilities, it is easy to favour the popular/preferred and dismiss the less popular features in landscapes. Our findings show that this might not be the best practice, because what might be labelled as undesirable could actually be used as an advantage.

*Potential for Future Research*

The experiment successfully demonstrated that a virtual experience of skiing in a winter landscape can deliver a degree of restorativeness (at least in the context of self-reported survey results), thus answering research question 1. There are several aspects we might wish to develop in further experiments in terms of variables which might be tested. One of these is the layout and design of the clear-cut areas. The practice of forest landscape design has aimed at ways to reduce the negative impacts of forest cutting, proposing less-geometric layouts which appear more naturalistic and retaining dense clumps of trees, which break up the visual extent and provide a more varied and dynamic visual experience when walking, cycling, or skiing [15]. Testing a landscape which also included stands of trees of different heights and densities, representing varying ages, would also reflect realistic conditions. Results of such work could also inform the creation of a virtual model which could have use in therapeutic roles [41].

One major difference between a real skiing experience and a virtual one, and which is likely to play a very significant part in the overall wellbeing of skiers, is that of the physical activity of skiing itself, the exposure to fresh air, a full-body workout, and the associated endorphin boost. However, while it is easy to measure such benefits, the restorativeness aspect may not be, so that the use of virtual reality experiments could add to our knowledge of the overall benefits to health and well-being.

## 5. Conclusions

The overall aim of the study reported here was to test the potential use of a virtual forest created in a 3-D landscape simulator, where the visual characteristics of the forest can be precisely controlled, and the simulated movement gives the opportunity to study aspects related to preference and restorativeness. In relation to research question 1, whether a virtual reality environment can deliver a restorative experience, we can answer yes, at least partly according to the scale we used, but that the absence of actual skiing and the restorativeness of the physical activity in the real landscape within the experiment does not give the complete picture. Nevertheless, it may be concluded that with further work, a virtual skiing experience could be created which could have potential to provide restorativeness to people unable to go skiing themselves—perhaps housebound older people who used to ski actively when younger.

The second research question related to the first: whether there are effects emanating from the ordering of the visual stimuli or effects of habituation and boredom in the restorativeness scores given to landscapes experienced as a longer continuous sequence. Once again, the answer to this question was that this is indeed the case and it leads to conclusions about the role of landscape diversity, the degree or amount of diversity experienced at different speeds and it suggests some aspects which could be relevant in the design of ski routes as well as the design of the virtual models to be used in "virtual health" activities.

There are some notable limitations which emerged in part as a result of the success of the experiment—there are more variables which could or should be tested; the absence of real skiing in the overall restoration or health and well-being outcome is something to be explored further. These lead to suggestions for further interesting research using VR as an experimental tool.

While practical application of the results is still limited due to the fact that not all possible variables found in forest landscape or the options open to forest managers were included, nevertheless, they can be used by recreation planners considering how best to lay out a ski trail so as not only to provide the best physical exercise and to maximise the use of the terrain, but also to avoid places where the landscape could be boring, such as extensive clear cut areas or any long monotonous stretches through visually impermeable forest.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12020422/s1, file data_winter_sequence_ABC.csv: data presented in this study.

**Author Contributions:** Conceptualization, P.V. and S.B.; methodology, P.V. and S.B.; validation, P.V. and S.B.; formal analysis, P.V.; investigation, P.V.; resources, P.V.; data curation, P.V.; writing—original draft preparation, P.V.; writing—review and editing, P.V. and S.B.; visualization, P.V.; supervision, S.B.; project administration, S.B. All authors have read and agreed to the published version of the manuscript.

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## Appendix A

### *Appendix A.1. Survey Form in Estonian Language*

metsamaastik nr 2

**C: Kujutle, et viibid päriselt selles maastikus. Kirjelda, missugune on su kognitiivne reaktsioon.**

Ma olen sellest maastikust huvitatud

(üldsegi mitte) - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - (tõesti, väga)

Ma tunnen end sellest maastikust paelutuna

(üldsegi mitte) - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - (tõesti, väga)

**B: Kujutle, et viibid päriselt selles maastikus. Kirjelda, kuidas sa käituksid.**

Mulle meeldiks siin sagedamini käia

(üldsegi mitte) - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - (tõesti, väga)

Mulle meeldiks siin kauem viibida

(üldsegi mitte) - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - (tõesti, väga)

**E: Kujutle, et viibid päriselt selles maastikus. Kirjelda, missugused on su emotsioonid.**

Mossis Heas tujus

(vägagi) - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - (vägagi)

Ärev Pingevaba

(vägagi) - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - (vägagi)

**F: Kujutle, et viibid päriselt selles maastikus. Kirjelda, missugune on su füsioloogiline reaktsioon**

Mu hingamine kiireneb

(üldsegi mitte) - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - (tõesti, väga)

Mu käed muutuvad higiseks

(üldsegi mitte) - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - (tõesti, väga)

**Figure A1.** Survey form of the Short Revised Restorativeness Scale [33] in Estonian.

*Appendix A.2. Example Images Depicting All Seven Forest Models Used in the Study*

**Figure A2.** 0—Introduction to survey form and realism.

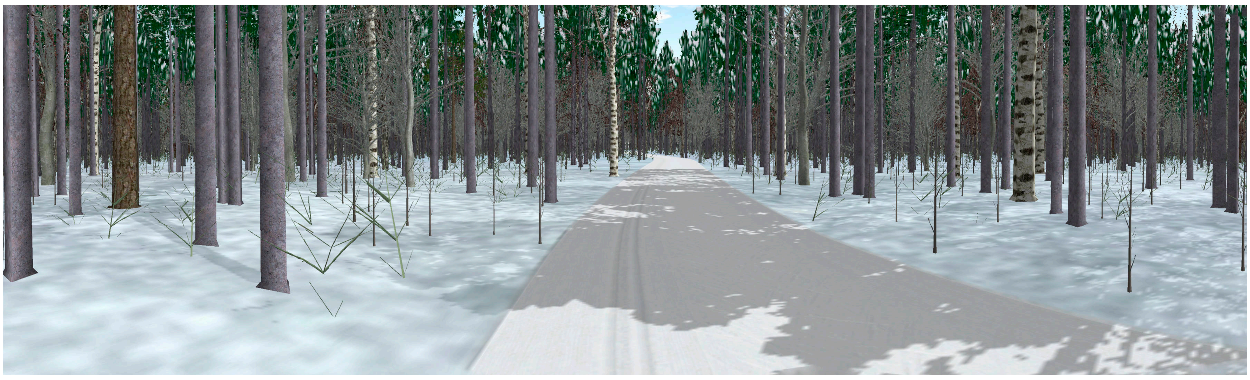

**Figure A3.** 1—Dense forest, no clearings.

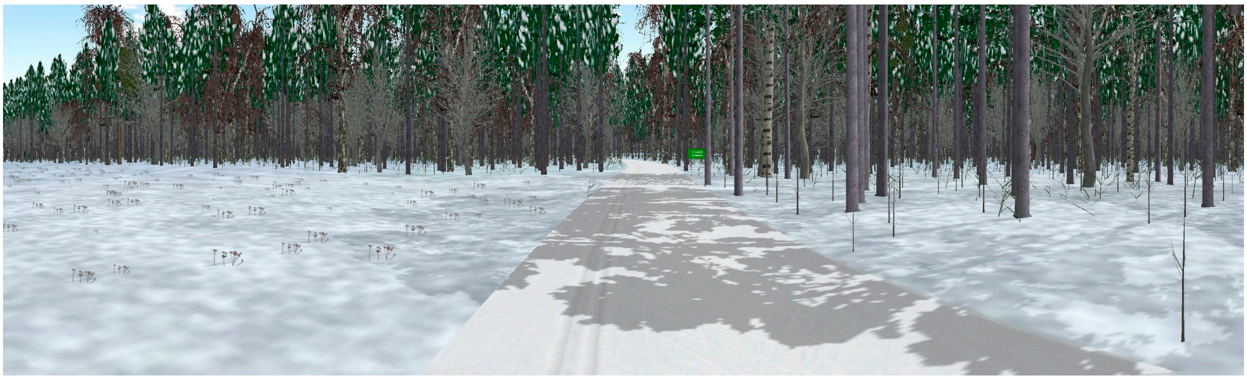

**Figure A4.** 2—Dense forest, large and few clearings.

**Figure A5.** 3—Dense forest, small and numerous clearings.

**Figure A6.** 4—Sparse pine forest, no clearings.

**Figure A7.** 5—Sparse pine forest, large and few clearings.

**Figure A8.** 6—Sparse pine forest, small and numerous clearings.

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