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Testing the Effect of Hedge Height on Perceived Safety—A Landscape Design Intervention

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Abstract: Access to safe, green urban environments is important for quality of life in cities. The objective of this study is to explore the impact of a safety-enhancing landscape design measure on visitors' experiences in an urban park. Additionally, this paper combines the use of field and virtual reality (VR) experiments, contributing methodological insights into how to evaluate safety measures in green space management and research on perceived safety. In a field experiment ($n = 266$), we explored whether the height of a hedge along a pathway influenced perceived safety among users. The field study showed that cutting down the hedge improved the perceived prospect of the immediate surrounding areas for female users, which again made them feel safer in the park. We developed a VR experiment for an evening scenario in the same environment ($n = 19$) to supplement the field study and test the effect of the intervention further. The VR experiment also found a gender effect on perceived safety, with females reporting lower perceived safety, but no effect was shown for the height of the hedge. The results in this study show that environmental attributes such as perceived prospect and concealment should be considered in the design and management of urban green spaces. Additionally, this research demonstrates an approach to conducting field experiments to test the effects of actual design interventions and then further developing these experiments using VR technology. Further research on perceived safety in outdoor spaces is needed to make use of this combined method's potential.

Keywords: green space management; fear of crime; vegetation; perceived prospect; entrapment and concealment; virtual reality

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1. Introduction

Access to safe green urban environments is important for quality of life among urban dwellers [1–3]. Studies have shown that more green coverage in cities can be related to lower crime rates (e.g., [4–6]), as well as perceived safety among residents [7]. However, the character of the vegetation in public green spaces can also be related to crime because smaller, view-obstructing trees have been shown to be associated with higher crime rates, while larger trees were associated with reduced crime [8]. Fear of crime in urban parks may prevent people from using urban green spaces [9,10], and several studies have shown that women's experiences of safety and actual use of urban green spaces differs from men's [11–13]. This accentuates the issue of equal access to green spaces, which is related to the United Nations 11th Sustainable Development Goal to create inclusive and safe cities [14].

Internationally, crime prevention through environmental design has been applied in planning practice in large cities, but a practical scheme for handling safety issues in landscape design—and green space management in particular—seems to be lacking, especially in the Nordic context [15,16]. In a review of the fear of crime in urban green spaces, Sreetheran and van den Bosch [17] present a socio-ecological model demonstrating the interplay between individual, social and physical factors as a way to understand the complexity of fear of crime. Evensen et al. [16] further highlight the context dependency of perceived safety in urban parks, emphasising the need to account for physical environmental features, such as perceived prospect in green space management.

Several empirical studies have focused on perceived safety and green spaces at the neighbourhood level (e.g., [18,19]). However, fewer studies have assessed how environmental features, such as vegetation arrangement, affect perceived safety on a design level. In their review, Sreetheran and van den Bosch [17] show that landscape designs that provide users with a clear view of the park are important for perceived safety. Hence, further attention should be payed to design-related features such as the type, density, height and maintenance of vegetation that can affect view or perceived prospect.

Unimpeded and long-distance views in parks offer prospects that can create a sense of control over the environment. Prospect-refuge theory [20] holds that people prefer landscapes that offer both prospects (visual control over the potential dangers in the environment) while also providing refuge (a place to withdraw and privacy). These physical attributes can include foliage, such as bushes or trees. Perceived low prospect and low refuge in green spaces have been shown to increase stress [21]. A study exploring tree coverage and stress recovery [22] found that tree density along a street had a stronger positive effect on stress recovery after exposure to medium tree density compared with low and high densities. However, in the study, this response pattern was found only among men.

The preferred level of perceived refuge in the daytime, however, can pose a threat at night by providing a potential hiding place for perpetrators. Hence, the greater the density or level of perceived concealment that the vegetation provides, the more fearfulness it can invoke [11,23,24]. Jiang et al. [25] found that neatly cut vegetation was perceived as safer than naturalistic, more freely growing vegetation in various experimental interventions, implying that both maintenance and visual accessibility are of importance to users. If vegetation such as bushes, trees and hedges also act as barriers to movement, they can create a sense of entrapment, which is another physical environmental attribute that has been shown to be related to perceived safety [26]. In their study, Blöbaum & Hunecke [26] found that perceived entrapment predicted perceived danger even stronger than gender.

The studies above show how landscape design through the management of vegetation can influence the experience of green spaces in terms of perceived safety (see also [27]). Some studies have explored the impact of vegetation structures along paths on park users' preferences and perception of safety in particular (e.g., [28,29]), however more studies are needed. There is a need for more knowledge about how the different designs of vegetation within parks impact perceived safety. This knowledge is particularly important for green space management, both for new park designs and the maintenance of existing ones. A certain level of perceived refuge is important for recreational areas because open lawns with no bushes and few trees can inhibit one's privacy, decreasing the recreational value of the space. Hence, there is a need to identify at what point the amount or height of vegetation goes from being highly preferred to becoming perceived as unsafe.

Many studies are photo based or use photo montages, maps or sketches to present various environments or environmental designs [17]. There is a need for experimental field studies to explore the actual effects of park safety-enhancing measures. However, relying on field experiments alone for studying perception of safety can be limiting, time-consuming and resource demanding. Examples include restriction for site access; fear or unwillingness of participants to walk through unfamiliar sites; selection bias in recruitment of park users at night or in places with the reputation of being unsafe; and difficulties recreating the required conditions for evaluation (e.g., winter, summer or night-time). Therefore, there is a need to experiment with new, flexible methods to explore park safety.

The latest developments in digital visualisation techniques that are represented by the advances made in VR technology are providing new potential to increase the level of realism and presence for subjects when it comes to studying perceived safety in outdoor spaces [30,31]. Contrary to the use of static photos, VR provides participants with the possibility to explore scenarios from several perspectives by using a head-mounted display (HMD) device [32]. Supplementing field studies with experiments manipulating the same environments in VR seems to be useful for the evaluation of safety measures in green space management, as well as in applied research on perceived safety.

Objective

The objective of the current study was to explore the impact of a safety-enhancing landscape design measure on park visitors' experiences in an urban park in Oslo. Using both a field experiment and virtual reality (VR) experiment with an evening scenario in the same environment, we explored whether the height of a hedge along a pathway influenced perceived safety among users. A low hedge was expected to provide higher perceived prospect and lower perceived entrapment and concealment and, thus, would be perceived as safer than a tall hedge. By supplementing the field experiment with a VR experiment, we also sought to contribute methodological insights into the evaluation of safety measures in green space management and in applied research on perceived safety.

2. Materials and Methods

2.1. Study Design

The current one-year study was designed with pre- and postintervention measurements of perceived safety among park users. Two experimental studies were conducted: a field experiment and an explorative photo-based preference study using 360° spherical photos presented with VR goggles (see Table 1). These allowed for different degree of experimental control.

Table 1. Experimental designs.

Methods	*n*	Hedge Height	Time of Day
Field experiment	254	Low, tall	Day
VR experiment	19	Low, medium, tall	Evening

VR: virtual reality.

2.2. Study Site and Landscape Design Intervention

The park is located in a densely populated area in central Oslo, Norway. It is a large park (136 acres) situated in the valley Torshovdalen [33]. The park offers viewpoints of the city and the fjord, open lawns and hilly topography and is an important area for recreation, while also being a thoroughfare for the local residents. Along an approximately 250 m pathway in the park rests a hedge (~2 m tall) consisting of *Spiraea* spp. (see Figure 1). Users in the neighbourhood have complained to the Department of Green Space Management of the Oslo municipality about low visibility and feelings of unsafety along this pathway. Thus, plans were made to cut the hedge. This gave us an opportunity to explore how the pathway would be perceived by users before and after the hedge was cut.

2.3. Field Experiment

For the field experiment, on-site park surveys with users on their experiences of the park pathway were conducted before and after the intervention. These surveys were conducted in mid-September 2015 (before intervention) and in mid-May the following year (after intervention). The hedge was cut in November, and thus the delayed date of the second assessment avoided a potential novelty effect. The field experiment was set up as a between-subjects design. Figure 1 provides photos of the before and after conditions.

(**a**) (**b**)

Figure 1. Photos of the pathway (**a**) before the intervention (tall hedge) and (**b**) after the intervention (low height hedge).

2.3.1. Participants and Procedure

Park users were randomly approached by research assistants at the beginning of the pathway and asked to respond to a survey about their experiences of the park when looking down the pathway, as shown in Figure 1. The surveys were conducted between 3 and 6 p.m. over nine days (both workdays and weekends) in September (before the intervention) and 10 days in May (after the intervention). The time of day was chosen based on the observations of the most park users available. Table 2 describes the background variables of the participants. Only participants over the age of 18 years were recruited for the survey. The sample is a convenience sample, and even though the research assistants were instructed to recruit a mix of people according to age and gender, the table of the background variables shows that the sample is skewed. The research assistants did not keep a record of how many people they stopped, so information on nonresponse is lacking.

Table 2. Background variables of the field survey participants before and after the intervention. [1]

Demographic	Before Intervention (%)	After Intervention (%)
Gender		
Female	65	47
Male	35	53
Age		
<30 years	43	18
30–59 years	46	68
>60 years	11	15
Education		
Secondary school	20	6
University/college < 4 years	35	36
University/college ≥4 years	46	58
Familiarity with park		
Less than daily visits	52	34
Daily visits	48	66
Previous negative park experience		
Never	69	86
Once	20	6

[1] n = 81 (before intervention); n = 166 (after intervention).

2.3.2. Questionnaire

In the first survey before the intervention, the participants were randomly assigned to one of two scenarios: (A) imagine walking down the path alone during the day or (B) imagine walking down the path alone in the evening. In the second survey, after the intervention, all the participants were given Scenario B because we found the evening condition to be more relevant to perceived safety. The participants were asked to indicate the extent to which several statements on perceived environmental attributes and perceived safety described how they would feel, here based on a scale from 1 to 7.

The items were selected from existing instruments used for assessing perceived safety in public space [23,26,34,35]. The perceived environmental features we found relevant for the study site were perceived prospect, concealment, and entrapment (Table 3). Perceived prospect and concealment seem somewhat related, but it has been shown that they can be assessed as separate entities [23]. In our case we wanted to assess how the intervention influenced perception of prospect, but at the same time captured the users' potential worries of perceived concealment. We therefore chose to assess perceived concealment, rather than perceived refuge, because of the dual quality of perceived refuge, which can be both positive and negative depending on the context and time of the day.

Table 3. Items in the questionnaire used in the field survey.

Outcome Variable	Items
Perceived environmental attributes Prospect	From this place I have a good overview; Is it easy to see far without getting the view blocked?
Concealment	Are you worried about what can be around you here?; Are you worried about what can be behind you here?)
Entrapment	Can you easily get away from this place?; Is it easy to move here?
Perceived safety	I feel safe here; I feel anxious here (reversed); I can walk here by myself; I would walk a long way to avoid this place (reversed)

The four items covering perceived safety (Table 3) comprised a total measure of perceived safety. The measure had high reliability, with a Cronbach's alpha of 0.96. In the second survey (after the intervention), we added questions about the intervention itself: *Have you noticed that the hedges are cut down here? Did the removal of the hedges make you feel safer here?*

Based on knowledge from previous studies, we controlled for the personality trait of emotional stability (neuroticism) and familiarity with the place. We used the emotional stability scale from the brief version of the Big Five Inventory [36]. The scale assessed how the participants rated the accuracy of the following descriptions to describe them on a general basis, here on a scale from 1 to 7 *(relaxed and tackles stress well, is depressed, worries a lot, and is easily nervous).* The measure proved to have satisfactory reliability, with a Cronbach's alpha of 0.8. Familiarity was assessed with the following item: *How often have you visited this place?* (scale of 0 to 4, where 0 is never and 4 is almost daily).

2.4. Virtual Reality Experiment

An experimental preference study using VR technology was conducted to further test whether the height of the hedge along the park pathway influenced perceived safety in an evening scenario and to explore the applicability of this technology in a landscape design intervention study. The study was set up as a randomised experiment with a within-subjects design.

2.4.1. Participants

The participants were randomly recruited bachelor students from the Norwegian Inland University of Applied Sciences. Females accounted for 53% of the participants, and the mean age was 22.4 years (SD = 2.7).

2.4.2. Stimuli and VR Setup

The VR setup used at the time of the study (2016) was based on using 360° spherical images of the pathway captured at eye height (170 cm) on four different spots along the park pathway. The 360° spherical images were captured with a 360-degree camera (Richo Theta

S) with a resolution of 5376 × 2688 pixels per inch. The photos were shot in mid-September, right after the hedge had been cut down. These photos represented the low height hedge. The photos were manipulated in Photoshop to recreate two design alternatives: a one-metre-tall hedge along the pathway (medium height) and another scenario with a two-metre-tall hedge (tall height). The photos were then further manipulated to represent an evening condition (see Figure 2). The three scenarios were loaded into a mobile-based VR headset (Samsung Gear VR). Samsung Gear VR relies on using a smartphone to deliver the VR experience. The headset and its corresponding smartphone (Samsung Galaxy S7) delivered a resolution of 1280 × 1440 pixels per inch per eye with a 60 Hz refresh rate and a 101-degree field of view. The participants were able to teleport between the four locations by focusing on a teleportation node while experiencing the VR environment scenario. The technical connection and teleportation processing between locations was made with the desktop application "Kolor Panotour Pro" and viewed with the "Panotour Viewer" application for Android.

Figure 2. Snapshots from 360° spherical photos for the evening scenario of the pathway used in the VR experiment: (**1**) tall-height hedge condition, (**2**) medium-height hedge condition and (**3**) low-height hedge condition.

2.4.3. Procedure

The experiment was conducted with groups of three to five participants at a time. First, they were informed about the experiment and signed an informed consent form. Then, they went through a trial assessment of 360° spherical photos of a campus park to get used to wearing the VR goggles and the teleportation process. The groups were then presented with the environmental conditions in random order to counterbalance any order effect. They were asked to look around, then teleport to another location further down the pathway two times and then return to the starting location. There, they assessed the pathway while looking down it, which was similar to the field experiment. The questionnaire was read aloud to the participants by one of the researchers and they responded on a scale from 1 to 5 by holding up their fingers. Their responses were recorded by the researchers. The participants had a break lasting for a few minutes between each of the three assessments to rest and avoid dizziness from wearing the VR goggles. A short version of the questionnaire was applied to make the procedure quick. After the final assessment, the participants were asked whether they had noticed a difference in the presented environments and were debriefed by the researchers. The experimental procedure was developed as part of a teaching programme for students in landscape architecture and environmental psychology courses.

2.4.4. Questionnaire

Each environmental condition was assessed with the short version of the questionnaire used in the field experiment. The perceived physical environmental attributes assessed were prospect (*From this place I have a good overview*), entrapment (*Can you easily get away from this place?*) and concealment *(Are you worried about what can be around you here?*). The items covering perceived safety were the same as in the field experiment (see Section 2.3.2). The four items comprised a total measure of perceived safety, which had a satisfactory reliability with a Cronbach's alpha of 0.80 to 0.92.

2.5. Data Analysis

The analysis of the data from the field experiment was done with SPSS AMOS graphics version 27 (IBM). As can be seen from the descriptive results (Table 4), there were several differences between the field experiment samples in the two study periods. Hence, we needed to control for this. Because we assumed that the intervention (cutting down the hedge) could have an effect on both the perceived environmental attributes and perceived safety, we were interested in looking at the mediating effects. To account for this, we formulated a multivariate model using structural equation modelling (SEM). There are two components in a structural equation model: the measurement model and structural model. The measurement model describes the relations between measured and latent variables and can be compared with what is done in a traditional factor analysis. The structural model describes the relationship between the observed variables.

Table 4. Descriptive results of the field survey on perceived environmental attributes (prospect, entrapment and concealment), perceived safety and emotional stability before and after intervention.

[1] Outcome Variable	Score	
	Before Intervention	**After Intervention**
Prospect	4.3	4.7
Concealment	4.6	4.8
Entrapment	2.9	2.7
Perceived safety	5.4	5.5
Emotional stability [2]	2.7	2.2

[1] n = 81 (before intervention); n = 166 (after intervention). [2] Emotional stability measured using the Big Five Inventory.

We first formulated a model for the whole sample. To account for a potential interaction effect with gender, we split the sample and ran separate models for males and females. In all models, the final outcome variable was the latent variable. Perceived safety comprised the four measured variables. The background variables were gender, age group, the latent variable for emotional stability, framing (day/night) and a dummy variable for before/after intervention.

We assessed model fit by looking at the chi square probability level (*p*) [37]. We also looked at the goodness-of-fit index (GFI) and the adjusted root mean square error of approximation (RMSEA), as well as the chi square/degree of freedom ratio, which is also known as the relative chi square [38]. A rule of thumb is that the chi square should be less than two times its degrees of freedom.

Data from the VR experiment were analysed with SPSS version 27 (IBM) using a mixed analysis of variance (repeated measures ANOVA).

All data were anonymous, and the research project was registered with the Norwegian Centre for Research Data.

3. Results

3.1. Field Experiment

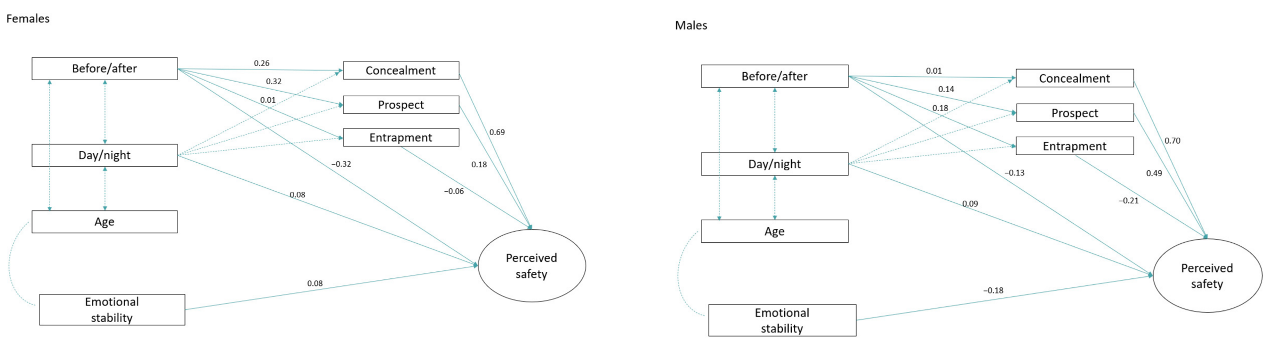
3.1.1. Descriptive Results

Looking at the bivariate relationships, the intervention had little effect on the outcome variables for perceived environmental attributes (prospect, entrapment and concealment) or perceived safety. There was, however, a significant difference in the mean score for emotional stability ($p < 0.001$) (Table 4). In the after-intervention situation, 45% of the participants reported that they had noticed that the vegetation had been cut down. Of these, 61% said that the change had made the park a little or much safer.

3.1.2. Structural Equation Model

The model for the full sample showed slightly less than an acceptable fit to the data (cmin/df = 5.5, $p = 0.00$; RMSEA = 0.14). Modification indices were used to improve the model along the most relevant paths, but some suggested paths were not included because they did not substantially contribute to the research questions. Including them would have improved the model fit and, thus, could have rendered the *p*-value significant (as it should ideally be) but would not have altered the main conclusions below.

The model for the male sample showed a better model fit (cmin/df = 2.5, $p = 0.00$; RMSEA = 0.12) than the full sample model, as did the model for the female sample (cmin/df = 3.3, $p = 0.00$; RMSEA = 0.13), indicating an interaction effect between gender and the outcome variables. Therefore, we only focus on the separate models for males and females from this point on (Figure 3).



(**a**) (**b**)

Figure 3. A summary of the direct effects between the most important variables in the SEM model for (**a**) females and (**b**) males. Dashed lines are measured relationships that are not presented with parameter estimates (for clarity).

Figure 3 is a summary of the direct effects on the most important variables in the model for females (left panel) and males (right panel). All covariates and measurement variables for the latent variables are omitted for ease of interpretation. Standardised total effects (direct and indirect) on the main variables in the structural models are summarised in Table 5, and the complete models with all covariates and error terms are found in Figures A1 and A2 in Appendix A.

Table 5. Standardised total effects of the condition (before/after intervention) on the main mediating and dependent variables for females and males.

Outcome Variable	Standardised Total Effect	
	Females	**Males**
Prospect	0.32	0.14
Concealment	0.26	0.02
Entrapment	−0.15	−0.22
Perceived safety	0.32	−0.01

Figure 3 shows that the direct effect of the intervention on perceived safety when also controlling for the paths via intermediate variables was negative for both females (−0.32) and males (−0.13). However, because of the path estimates from the intervention to perceived concealment, prospect and entrapment, as well as from these variables to perceived safety, the net effect is that the total effect of the intervention on perceived safety was positive for females (0.32), but there was no difference in perceived safety for males (Table 3). The total effects on prospect and concealment were also higher for females than for males, whereas the effect on entrapment was slightly higher for male participants. The interpretation of the difference between the total effects and the direct effects indicates that, for females, the effect of the intervention is fully mediated by the variable prospect and partially mediated by the variables of concealment and entrapment. For males, there was no change in perceived safety, even if they also appreciated the increased prospect and decreased entrapment (no change in concealment). Regardless of the intervention, concealment was the variable that was most closely linked to perceived safety for both males and females. To summarise, the main effect of cutting down the vegetation was that female visitors experienced a better prospect over the immediate surrounding areas, which again made them feel safer in the park.

3.2. Virtual Reality Experiment

An analysis was conducted to compare the effect of hedge height along the pathway (low, medium or tall) in an evening scenario on perceived safety and explore whether gender affected this environmental experience. A mixed analysis of variance (repeated measures ANOVA) was conducted, with the perceived safety of the height of the hedge as the within-subjects factor and gender as the between-subjects factor. Hedge height had no significant main effect on perceived safety, F (2, 34) = 1.25, p = 0.30, ■^2_p = 0.07. However, gender did have a significant main effect on perceived safety, F (1, 17) = 15.26, p = 0.001, ■^2_p = 0.47, with the female participants reporting consistently lower perceived safety than the male participants across environmental conditions (Table 6).

Table 6. Mean score for perceived safety across environmental conditions (low, medium, and tall hedges) for females and males in the VR experiment with an evening scenario.

Perceived Safety	Females M *(SD)*	Males M *(SD)*
Low hedge	2.5 *(1.0)*	4.1 *(0.5)*
Medium hedge	2.8 *(0.7)*	3.8 *(0.7)*
Tall hedge	2.5 *(0.9)*	3.7 *(0.9)*

There were no differences in perceived environmental attributes (prospect, entrapment and concealment) across the experimental conditions or between males and females. Thus, further analyses of the perceived environmental attributes are not presented. After the experiment, only two participants reported that they had noticed a difference in the height of the hedges while they were in the virtual environment.

4. Discussion

The main objective of the current study was to explore the impact of a safety-enhancing landscape design measure (the height of a hedge) in an urban park in Oslo. We also wanted to explore an approach to evaluating safety measures in green space management.

First, the results of the field experiment uncovered an interaction effect between gender and the various outcome variables. The intervention influenced women's reports of perceived safety, which can be explained by the fact that cutting down the hedge led to a greater perceived prospect, which again were related to greater perceived safety. The intervention also led to lower perceived entrapment and concealment of the pathway, but these perceived environmental attributes could only partially explain the effect on perceived safety. The VR experiment supplemented the field study by exploring the effect of hedge height on perceived safety in an evening scenario. The findings from the VR experiment also showed a gender difference in the levels of perceived safety, with female participants reporting lower perceived safety, although the study could not detect a direct effect of the height of the hedge on perceived safety. Previous studies have also shown that women report more fear of crime and lower perceived safety in green spaces [11]. Safety issues regarding green space management seem to benefit from taking a socio-ecological approach that considers individual differences in experience of public space [17]. Certain studies have taken on the aim of disentangling gender differences in perceived safety in public space (e.g., [25]), and some have conducted studies on female park users only, in order to explore their particular needs in terms of safety [16,28]. The findings indicating gender differences in experience of green spaces show that safety-enhancing measures should be prioritised in green space design along with management to ensure equal access and benefits of green spaces [13], which is in line with United Nations 11th Sustainable Development Goal to create inclusive and safe cities [14].

Second, in the field experiment, the perceived environmental attribute prospect, which was shown to be linked to the design intervention, removing the hedge, actually influenced the outcome of perceived safety (among females). This finding further confirms the impact of the design intervention on users. This mediating effect supports the internal validity of the finding, something which could be difficult to conclude in field studies and a cross-sectional between-subjects design, such as the one used here. Furthermore, although perceived concealment did not show a full mediating effect on perceived safety, it was the environmental attribute that had the strongest relation to perceived safety for both genders and, thus, seems to be an important environmental feature to consider in landscape design. The SEM model indicated that the direct effect (what was left when controlling for changes in prospect) of the intervention on perceived safety was negative, especially for females. This negative direct effect indicates that park users who did not perceive any change in prospect, concealment or entrapment actually felt less safe after the vegetation had been removed. However, there were not many of these users, so the total effect of the intervention was still positive. Finally, 61% of the participants who had noticed the landscape intervention reported that it had improved the perceived safety of the park, further supporting the impact of the safety measure.

The results show how landscape design can affect perceived prospect and concealment in urban green space and that these environmental attributes were related to perceived safety among users. These findings are in line with previous studies [23,26,27], indicating that perceived prospect and concealment are environmental attributes that should be considered in vegetation design, especially with respect to how parks and green spaces are experienced during the evening and night-time. A particular focus should be on vegetation arrangement along paths, to avoid unnecessary fear and worry that can lead to behavioural constraints or prevent people from using or passing through green spaces [9].

Methodological Discussion

The current study also explored how safety measures in green space management, as well as applied research on perceived safety, can be investigated. First, we conducted two types of experiment with various degrees of experimental control. Interestingly, the VR experiment (with the more controlled environmental exposure and the within-subjects design) did not demonstrate the hypothesised effect of the design intervention, while the field experiment did. After the VR experiment, only two participants reported that they had noticed a difference in the height of hedges while they were in the virtual environment. Although instructed to look down the pathway, the participants may have focused on other details while in the VR environment besides the pathway, or it may have been that the differences between the environmental conditions were less detectable compared with the daytime field study because of the dimmed lighting/evening ambience.

In addition, the use of an evening scenario in the VR experiment could have had yet another impact on the results. The female participants reported relatively lower perceived safety than the females in the field study, averaging around the middle value on a scale of 1 to 5. This could imply that they felt somewhat unsafe in all environments (with various hedge heights) because of the dark evening scenario; thus, a difference in perceived safety between the environmental conditions should not be expected. This finding demonstrates the need to investigate the influence of various vegetation structures in evening and night-time scenarios to find landscape designs that are not perceived as unsafe after dark.

Furthermore, the items used to assess the perceived environmental attributes and safety should be carefully selected. In a previous study at the same study site [16] we did not find a relation between perceived refuge and safety. In this study, and in line with the discussion of the dual quality of perceived refuge [23,26], we found it useful to assess perceived concealment rather than refuge for reasons of interpretability. Another issue concerning the assessment, was the use of single-item measures in the VR-experiment. This choice was made to shorten the experimental procedure. With further developments of the quality of the VR experience, we would recommend multiple-item measures to ensure more valid assessments. Furthermore, the gender differences uncovered in the research field of perceived safety in green space are open to further exploration of how gender should be measured to provide valid knowledge about individual differences in perceived safety [26].

Finally, the setup of the VR experiment was the result of an explorative process of developing procedures on how to best use VR gear for research purposes. However, the novelty effect, because of the participants' unfamiliarity with using VR equipment, may have impacted the results, despite this setup. The use of VR has many advantages for internal validity compared with field studies [32]; however, the current study has shown that VR can also reduce the control of actual exposure compared with the use of 2D photo-based stimuli, which, in addition to the problem of dizziness may weaken its validity. Furthermore, VR has the potential to expand the possibilities for studying how various design features' influence perceived safety, supplementing field experiments that are limited by physical and practical issues. With the continuing developments of affordable VR technologies, it is expected that the level of presence and realism will improve, which will open up for the further development of experimental procedures that are useful for the evaluation of landscape design interventions.

5. Conclusions

The objective of the current study was to explore the impact of a safety-enhancing landscape design measure in an urban park in Oslo. In a field experiment and VR experiment of the same environment but as an evening scenario, we explored whether the height of a hedge along a pathway influenced perceived safety among the participants. The main conclusion of the field experiment was that the safety-enhancing landscape design measure, cutting down the hedges, in the studied park appeared to have the intended effect for female users but not male users. The supplementing VR experiment confirmed a gender difference in perceived safety, with females reporting lower perceived safety in the evening scenario but without the detection of a direct effect of the height of the hedges on perceived safety.

Behavioural constraints due to perceived fear in public space may be reduced with evidence-based design, planning and management. The results in this study show that environmental attributes such as perceived prospect and concealment should be considered in the design of urban green spaces.

Furthermore, the present study contributes methodological insights into how to evaluate safety measures in green space management and applied research. The study has shown that gender effects need to be carefully considered in applied research on perceived safety. Additionally, the present research has demonstrated the feasibility of an approach to conducting field experiments to test the effects of actual design interventions and then further developing these experiments using VR technology. Further research on perceived safety in outdoor spaces is needed to make use of this combined method's potential.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Appendix A

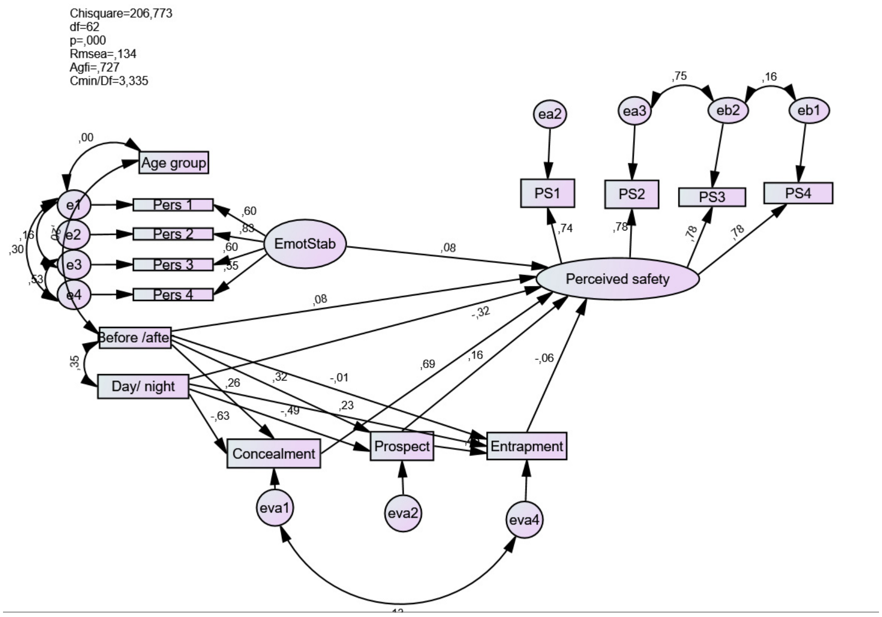

Figure A1. Full SEM model for female park users in the field experiment.

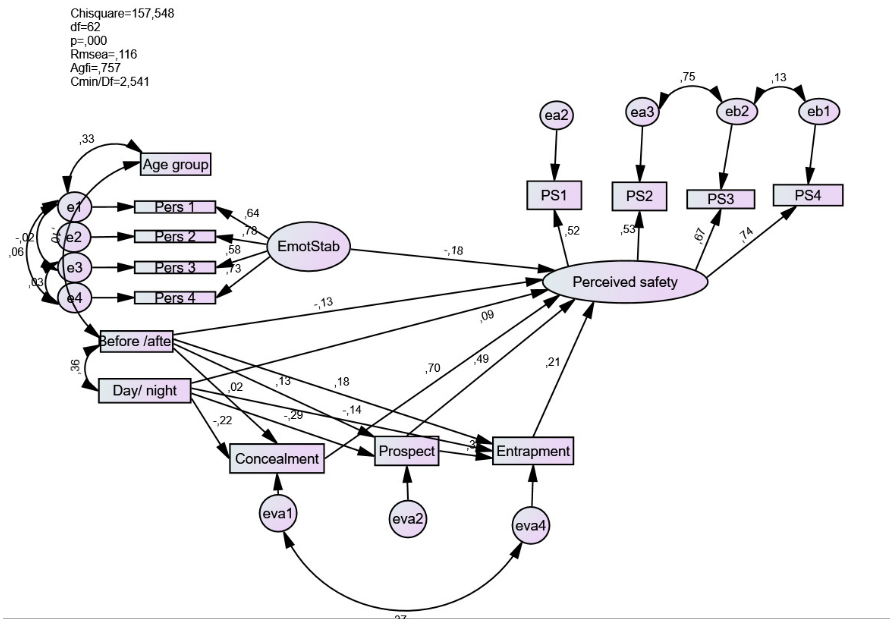

Figure A2. Full SEM model for male park users in the field experiment.

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