Exploring the Effects of Lighting and Permeability of Vegetation on Perceived Safety and Perceived Restorativeness in Urban Parks at Nighttime

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Exploring the Effects of Lighting and Permeability of Vegetation on Perceived Safety and Perceived Restorativeness in Urban Parks at Nighttime

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Summary

Urban parks are increasingly important in a world where cities continue to grow and densify. They have many beneficial effects on the environment and the people that visit them, such as improved air quality and biodiversity, better rain water storage, increased physical activity, reduced obesity, and decreased stress and mental fatigue. This report focuses on the decreased stress and mental fatigue, and its relevant aspects in urban parks.

There is a great body of research into why natural environments have a beneficial influence on stress and mental fatigue. At the base of this research two theories can often be found; the psycho-evolutionary Stress Reduction Theory (SRT) of Roger Ulrich and the Attention Restoration Theory (ART) of Stephen Kaplan.

Ulrich's work is essentially about preference of natural environments. In 1983 he put together a theoretical framework that proposes an explanation of how affects arise in the natural environment and links them to cognition, activity in physiological systems, and behavior. He theorized that pre-cognitive affective responses to an environment served adaptive needs, meaning that those who had a favorable, adaptive response to environments with beneficial characteristics for wellbeing were favored in evolution. The psychological benefits of natural environments were also researched by Ulrich, who found a clear pattern of restoration when participants were exposed to natural scenes. Conversely, urban scenes tended to negatively affect emotional well-being. Therefore, Ulrich theorized that exposure to unthreatening natural environments aids stress recovery and elicits positive emotional responses. Natural scenes should help to restore from stress by reducing negative affect, increasing positive affect, and decreasing physiological arousal.

During the '80s and '90s, Kaplan developed the Attention Restoration Theory (ART). In this theory, directed and involuntary attention play an important role. According to William James, directed attention requires effort, is important in focusing, is under voluntary control, is susceptible to fatigue, and controls distractions through the use of inhibition. Directed attention can be fatigued when one spends mental effort on something for a prolonged period of time. According to ART, restoration derives from recovery of directed attention fatigue. In order for recovery of directed attention to take place, involuntary attention should be used. Involuntary attention is said to not require effort, and thus is resistant to fatigue. While an individual is using involuntary attention, directed attention should be able to restore. Natural environments have been shown to require involuntary attention and therefore are potentially restorative places.

Both Ulrich's SRT and Kaplan's ART try to explain why natural environments provide restoration. However, they differ in the manner of explanation. Whereas ART is attention-oriented, SRT is stress-oriented and leaves no room for a significant role for attention. SRT state that it is the stress that leads to impaired cognitive performance, but ART states that the depletion of directed attention and the resulting mental fatigue is the cause of a stress response. Kaplan has tried to integrate the two theories and came up with a framework where both approaches fit in. The framework consists of three possible pathways or patterns that all eventually result in impaired performance. Overall, it suggests that a resource decline can lead to a stress response and a stress response can lead to a resource decline. Kaplan's integrated framework points to the existence of two distinct, but interacting, sources of restorative experiences.

However, the restorative potential of natural scenes might be constrained by low levels of perceived safety. Urban parks are often avoided at nighttime because they seem unsafe to people. When one is feeling unsafe, directed attention to the surroundings is needed to be ready for a possible threat, which leads to even more mental fatigue according to ART. In addition, Ulrich states in his SRT that a natural environment should be unthreatening in order to be restorative. If an environment elicits a negative

affective response, the restorative effect is absent. Perceived safety in urban parks can be influenced by many things, but this report limits its scope to the park features permeability (above and below the horizon line) and lighting. They are likely to influence perceived safety by affecting the vision and escape routes of a park visitor. In addition, permeability and lighting are also aspects that are expected to influence perceived restorativeness, due to the presence of more green and the visibility thereof.

How permeability and light influence perceived safety and perceived restorativeness at nighttime is not widely researched. Empirical evidence of what influence perceived safety has on perceived restorativeness is also lacking. Thus, the current study aims to investigate what relation light, permeability above the horizon line and permeability below the horizon line have with perceived safety and perceived restorativeness in urban parks at nighttime. Subsequently, it aims to find what influence perceived safety has on perceived restorativeness.

To answer the research questions a survey with nine walkthrough videos of about 20 seconds was made. In the videos, the levels of permeability above and below the horizon line and light were varied (3x3x3 design). Participants rated each on perceived safety or perceived restorativeness by means of close format questions. Afterwards, some demographical questions were asked and there was room to leave remarks. The survey could be made in a controlled laboratory setting or online on participants' own devices. A total of 118 people participated in the survey (61 males, 56 females, 1 gender-neutral, M_{age} = 24.8, SD_{age}= 9.0, age range = 18-59), of which 41 made it in the laboratory setting and 77 made it online.

Multiple series of multi-level models, nested within participants, were employed to test the effects of the main variables and the setting (laboratory-online). It turned out that permeability above the horizon line and light positively influenced both perceived safety and perceived restorativeness. Permeability below the horizon line did not have any significant effects.

For perceived safety, these results are somewhat unexpected. It was not anticipated for permeability above the horizon line to have significant effects, because this area of view does not seem to be important to establish good visibility of one's surroundings. The fact that it was, indicates that permeability above the horizon line might have an influence on factors that affect perceived safety after all. It was also unexpected that permeability below the horizon line did not result in any significant effects. This might be because the light was a prevalent factor in this area of view, perhaps even so much that it could have oppressed the influence of the permeability levels on perceived safety.

This might also be the reason for the absence of an effect of permeability below the horizon line on perceived restorativeness. For the models on perceived restorativeness, it was expected that the three levels of the permeabilities would result in inverted U-shape effects. Instead, the models showed that perceived restorativeness increased as the level of permeability above the horizon line increased. This indicates that an open view was preferred to a view obstructed with trees. A possible reason could be the starry night that became visible, which might have elicited some involuntary attention and perhaps even restoration.

Regarding the effect of light, it was expected that there is a positive linear effect between the amount of illumination and perceived safety and restorativeness. This turned out to be true for perceived safety; as the light levels increased, perceived safety also increased. However, for perceived restorativeness the effects of the second and third level were almost the same, so there seemed to be a limit to the restoration that can be reached by increasing the illumination levels.

When the average perceived safety per video was added to the multi-level models on perceived restorativeness, the results indicated that there was large multi-collinearity between perceived safety and the main variables (permeability above and below the horizon line, and light). The significant positive effect of perceived safety disappeared when the main variables were added. The results raised a question of what was measured exactly. It might be the case that the main variables are actually inherent to the perceived safety variable; they measure the same concept. This would indicate that predicting the perceived restorativeness with the perceived safety variable is redundant when the main variables are also included.

Furthermore, the observed effect of evaluating the videos in the laboratory or online suggests that online studies should be done with great caution. The participants that made the survey online reported higher perceived safety compared to those in the laboratory setting. Moreover, the light variable had no effect on perceived restorativeness when the survey was made online. A possible reason might be the difference between computer screens of the participants.

These effects show us that in online studies, especially where a visual evaluation is necessary, the results can be influenced by the different devices and surroundings. Ideally, online video studies should only be done when it is possible for every participant to use screens with similar visual qualities or when dependent variables are measured that do not rely on one's mental state. Otherwise, it might be a good idea to take the different environments into consideration by means of sensor applications (e.g. mobile applications that measure the illumination or sound) or adding questions about the surroundings to the survey.

There were some differences between gender. The perceived safety model showed that males reported higher perceived safety than females, but this effect was smaller when the illumination level increased, indicating that female participants are more sensitive to increases in illumination than males are. Conversely, no direct effect of gender on perceived restorativeness was found. What could be found is that male participants report higher perceived restorativeness in the laboratory setting and female participants do so in the online setting.

This study's main outcome that is relevant for designing urban parks is that permeability above the horizon line and light both had a linear positive effect on the dependent variables. Thus, they can be manipulated in the same manner to simultaneously increase perceived safety and perceived restorativeness levels. However, further research has to be done to be certain of this finding. Furthermore, other park characteristics (e.g. presence of other people, litter, benches, flowers, bodies of water, etc.) should be included in future research in order to get a broader, more complete understanding of the effects at play in urban parks at nighttime.

All in all, this study contributed to the knowledge on the relations between permeability, light, perceived safety, and perceived restorativeness. The results suggest that the main variables and the perceived safety variable are high in multicollinearity and are actually for a large part measuring the same concept. This indicates that predicting the perceived restorativeness with the perceived safety variable is redundant when the main variables are also included. Furthermore, although more research is needed on the topic, it can be said that the main result of this study is that either permeability or lighting can be manipulated in a similar manner to increase both perceived safety and perceived restorativeness. This will have to be confirmed in further research, but might eventually contribute to designing urban parks that are better places for one's psychological wellbeing.

1. Introduction

The importance of urban parks has been established in many studies over the last years. Next to environmental benefits, like improved air quality, biodiversity, and rain water storage, urban parks have benefits for the health and wellbeing of the people visiting them. They increase physical activity, reduce obesity, and decrease stress and mental fatigue for people living in proximity (Konijnendijk et al., 2013). As cities continue to grow and densify (United Nations, 2018), urban parks are increasingly important to expose an expanding number of people to a healthy environment.

There are many studies that have measured the reduction of mental fatigue and stress in natural environments (Canin, 1991; Cimprich, 1990; Grahn, & Stigsdotter, 2003; Hausmann, Hug, & Seeland, 2007). Subsequently, there also exists a large body of research into why natural environments have these effects on stress and mental fatigue (Kaplan, 2004). This largely originated from research into preference by, among others, Ulrich (1983). Ulrich reviewed the affective reactions associated with the visual perception of natural environments. He theorized that pre-cognitive affective responses to an environment served adaptive needs, meaning that those who had a favorable, adaptive response to environments with beneficial characteristics for wellbeing were favored in evolution. This would explain the positive affective response to unthreatening natural content, where one would find elements like water, food or shelter. He stated that an attractive natural view might induce feelings of pleasantness, hold interest, block or reduce stressful thoughts and therefore induce psychophysiological restoration. This theory was later called the psycho-evolutionary Stress Reduction Theory (SRT) (Ulrich, 1983).

Another theory explaining the beneficial effects of nature on stress and mental fatigue is Attention Restoration Theory (ART) of Kaplan (1995). Urban lifestyles generally impose a big demand on cognitive resources (Kaplan & Berman, 2010). This translates to a prolonged use of directed attention, which can lead to cognitive depletion and results in increased mental fatigue and stress. According to ART, restoration derives from recovery of directed attention fatigue. In order for recovery of directed attention to take place, involuntary attention should be used. Involuntary attention is said to not require effort, and thus is resistant to fatigue. While an individual is using involuntary attention, directed attention should be able to restore. Natural environments have been shown to generally require involuntary attention and therefore are potentially restorative places (Kaplan, 1995).

Kaplan (1995) has tried to integrate SRT and ART and came up with a framework where both approaches fit in. The framework consists of three possible pathways or patterns that all eventually result in impaired performance. Overall, it suggests that a resource decline can lead to a stress response and a stress response can lead to a resource decline. Kaplan's integrated framework points to the existence of two distinct, but interacting, sources of restorative experiences.

However, there is a factor that might constrain the restorative potential of natural environments; perceived safety. Many studies have shown that urban parks are often perceived as unsafe (e.g. Lis et al. 2019; Lis et al. 2021; Lis & Iwankowski, 2021a; Türkseven Dogrusoy & Zengel, 2017). These effects are mostly attributed to two characteristics, prospect and refuge, which refer to Appleton's prospect-refuge theory (1975). This theory states that the possibility to see (prospect) and not being seen (refuge) is basic to many biological needs. According to Appleton, an environment elicits preference if it suffices to accommodate enough prospect and refuge. However, the term refuge was found to be somewhat ambiguous, as it can be desirable when needed, but it can also become a source of danger when attackers hide in that same space. This is one of the reasons Fisher and Nasar (1992), and Nasar and Jones (1997) enhanced the prospect-refuge theory, adjusting and adding to the relevant environment characteristics that influence the perception of an environment. They argued that it was better to use the characteristics prospect, concealment and entrapment, rather than prospect and refuge. This proposed framework asserts that the total of these environmental qualities are used by people to infer the safety of an environment. There are several manners in which an urban park can manipulate these environmental characteristics, but some that are often investigated are altering the amount of vegetation and lighting. Adding vegetation results in less permeability, and decreases the level of prospect and increases the level of concealment and entrapment. Meanwhile, decreasing the illumination levels should reduce prospect and increase the opportunity of concealment and entrapment at nighttime. The resulting environments might be perceived as threatening and would require directed attention, which makes them less likely to feel restorative according to SRT and ART. On the other hand, it could be argued that more vegetation, and thus less permeability, leads to more natural environments, which would increase the restorative potential.

Although a large body of research into the effects of permeability and lighting on perceived safety exists, there is a lack of studies investigating the subsequent influence of perceived safety on perceived restorativeness in urban parks at nighttime. Thus, despite the theoretical influence of perceived safety on perceived restorativeness that is discussed in both SRT and ART, there is not much empirical evidence to be found on the subject. In addition, the influence of lighting, and the combination of lighting and permeability on perceived restorativeness seems an underdeveloped topic altogether. The current study will attempt to gain more insight in what is happening when manipulating the permeability and lighting levels of urban parks at nighttime. This results in the following three research questions (RQ):

RQ1: To what extent do light and permeability above and below the horizon line levels influence perceived safety?
RQ2: To what extent do light and permeability above and below the horizon line levels influence perceived restorativeness?
RQ3: To what extent does perceived safety influence perceived restorativeness?

To be able to understand the effects at work in urban parks at nighttime, it is important to first take a closer look into these restoration theories in all their aspects. In the next part of this report the theories and involved factors will we explained in greater extend, followed by the research aim and method of the experiment. The performed experiment consisted of a survey with several different videos where the permeability and lighting levels were manipulated. After watching the videos, participants were asked to answer rating scale questions about either perceived safety or perceived restorativeness. The data was then analyzed and the results discussed. At the end of the report a conclusion of the study is given.

2. Theoretical background

In this part of the report the theoretical background of the Stress Reduction Theory, the Attention Restoration Theory, an integration of the theories and the factors involved in perceived safety are explained and discussed.

2.1 Psycho-evolutionary Stress Reduction Theory

In 1983, Ulrich reviewed the then existing studies about aesthetic and affective reactions associated with visual perception of natural environments (Ulrich, 1983). From this information, he put together a theoretical framework that proposes an explanation of how affects arise in the natural environment and links them to cognition, activity in physiological systems, and behavior. The term affect is used synonymously with emotion, and aesthetic response is defined as preference in association with pleasurable feelings and neurophysiological activity evoked by a natural setting. Affects are defined as cross-cultural, innate phenomena, meaning one does not learn them, but is born with them (Izard, 1977). However, the cognitive processing of an affect can vary with factors such as age, culture, and experience (Izard & Buechler, 1980). Therefore, conscious experience changes throughout one's life as affective-cognitive structures are formed. For example, when an adult and a child both view the same natural scene, the effect on the quality or type of affect is the same, but the conscious experience may vary considerably because of differences in cognition. While reviewing the work, Ulrich found a clear theoretical trend that viewed affects as adaptive. This implicated that the elicited feelings of a natural view were favored by evolution, meaning that they were beneficial for the chance of survival. This was emphasized by the geographer Appleton (1975) who theorized that aesthetic pleasantness is a response to elements having significance for survival.

There has been debate in cognitive psychology about whether affects are precognitive or postcognitive. Zajonc (1980), Ittelson (1973), and Izard (1977) brought forth empirical support that many affects are precognitive and establish the initial level of response to an environment. Zajonc argued that the first stage of the response to a certain stimulus consists of generalized affects that are related to preferences, like fear or liking, and approach-avoidance behavior. This means you can be afraid of something without knowing what it is or why you are afraid of it. The initial response then significantly influences the following cognitive process. This would speed up recognition and increase the efficiency of information processing. Looking at the survival requirements in evolution, the increased processing speed and subsequent quicker approach-avoidance behavior would have great adaptive value. Zajonc (1980) argued that affects can be elicited with little information due to a collection of features he called preferenda. Preferenda are gross, often vague, structural aspects that can be effective in eliciting affect, but might be insufficient as basis for cognitive judgements. Examples are patterning or symmetry of settings, depth properties, and environmental content with survival potential (e.g. water, vegetation). So, when exposed to one or more of these preferenda, an affective response might be elicited, but no cognitive judgement can be formed yet. The intensity of affects induced by preferenda can be dependent on internal states of the individual, such as previous experience with stimuli of the same class, previous exposures that may produce contrast or similarity, and the individual's affective state prior to the exposure (Zajonc, 1980).

Different natural scenes can elicit different affective reactions (Ulrich, 1983). That is why it is important to consider the functions and consequences of these affects. The affective reactions are only part of the total behavior of the individual. For example, one might feel a strong preference for a certain setting, and have an impulse to explore the area further, but could suppress this behavior and stay where one currently is instead. Thus, it is assumed that an affective reaction motivates adaptive functioning or serves as a nudge towards that behavior, but the action does not need to be carried out. Many aesthetic and affective reactions to natural environments are assumably behaviors that are not necessarily observable actions, but they do qualify as adaptive functioning. If an observer's state prior to a natural scene is that of being stressed, that scene might elicit feelings of pleasantness, hold interest and block or reduce stressful thoughts, and therefore fostering psychophysiological restoration (Ulrich, 1979). This could occur even when simply continuing to view the scene and not taking any physical action.

There are several visual properties that influence affective reactions. The first discussed property is complexity, which refers to the number of independently perceived elements in a scene (Ulrich, 1983). When a scene is high in complexity it typically means that there are a large number of elements, with dissimilarity among these elements (Berlyne, 1971). High preference of natural environments tends to be associated with moderate levels of complexity. In contrast, low or high complexity are generally not preferred. However, high complexity natural scenes do elicit considerable interest or attention, whereas high preference scenes will not necessarily elicit strong interest (Berlyne, 1963; Day, 1967). This is because in unstructured high complexity environments the individual cannot quickly fathom the global aspects of the setting, and instead has to process it in more detail in order to get a good level of comprehension. Important information might be missed, which could prove dangerous in some situations. Therefore, a quick initial reaction of low preference is adaptive, because such affects generate avoidance behavior. Furthermore, the reaction in such a situation should also include interest, because this motivates attention and detailed processing. Thus, the complexity of a scene can contribute greatly to the initial level of response before recognition or identification has occurred.

Secondly, the framework assumes gross structural or configurational properties to be preferenda that elicit initial affective responses with minimal cognition (Ulrich, 1983). Human perception is strongly oriented to information that is structured or patterned. This would be adaptive because large number of elements could be grasped as chunks, speeding up recognition and identification (Ulrich, 1977). This implies that even highly complex scenes can be efficiently processed if their complexity is structured. Structuring can be established through the presence of homogeneous textures, redundant elements, and patterns. An important structural property is focality, which is the extent to which a scene contains a focal point, or an area that attracts the observer's attention. It is argued that focality is a configurational property that is important in eliciting initial affect and has a central role in the stages of processing and appraisal. Janssens (1976) investigated this with eye-fixation recordings and found that subjects immediately sought a salient feature or pattern, a focal area, when shown an outdoor scene. This focal point was often used as reference point for subsequent perception.

The third visual property is depth (Ulrich, 1973). Depth is said to have a positive relationship with aesthetic preference for natural or rural environments. A group of trees with some visual depth or openness is found to result in higher preference levels compared to tree groups with fewer depth (Brush, 1978). It is hypothesized that a low level of depth, such as a visually impenetrable view, can be an environment that quickly elicits dislike with minimal cognition. According to Appleton (1975), this is because there is a possibility of threats hiding in the enclosed space and opportunities of escape are lower. An important factor in defining depth is ground surface texture (Gibson, 1958). When the ground texture is even, more information tends to be extracted, and the observer should have a higher preference for the scene. Conversely, rough textures are often produced by physical obstacles, making the appraisal negative due to a lack of mobility (Ulrich, 1973).

Threat or tension is the fourth property. Threats should motivate adaptive impulses that urge the observer to avoid the place, accompanied with a strong dislike. This reaction should be elicited almost immediately, as an initial reaction, to keep the observer safe. Naturally, if an environment is regarded as threatening the preference for that scene is low. If a threat is hidden, the observer will not want to avoid immediately, but that response will be generated by the cognitive process in the following stages of the encounter.

Preference and curiosity are elicited when the line of sight in a setting is curved or deflected, which would signal that new information about the landscape is just around the corner. This property has been given different names by different researchers, namely anticipation (Cullen, 1961), deflected vistas (Appleton, 1975) and mystery (R. Kaplan, 1973; Kaplan, 1975). In this report it will be called deflected vistas. The property is very cognitive and therefore has no major part in the initial affective reaction. However, it is argued that humans nowadays innately like exploring deflected vistas, because of the benefits it yielded during evolution (Kaplan, 1975). Ulrich (1983) adds that deflected vistas will result in a preference for the scene only if the observer thinks the new information can be obtained safely.

The last visual property that is said to influence affective reactions is water. Water has been shown to evoke interest, aesthetic pleasantness, and positive feelings (Hubbard & Kimball, 1967). A scene with water features usually results in high levels of preference and enhances scenic quality. The reason for this phenomenon is debated. One explanation could be that the preference is biologically based and dependent on learned association, since water is needed in order to survive. Another explanation may be that the water serves as a focal point, a term that was previously discussed. Water could also increase subjective depth, because a body of water can be visually open but often has depth cues (Hubbard & Kimball, 1967).

These properties have been substantiated in Ulrich's (1977) research into predicted preference of natural environments. He reported subjects to have moderately high to high preference for scenes with at least midrange values for complexity, focality, depth, and even ground texture. The most-liked environments tended to be parklike with generally scattered trees and even ground textures. Here, the trees create depth cues in the open space provided by the even ground surface.

Next to the aesthetic preference elicited, it is also widely believed that experiences with natural environments can be psychologically healthful (Driver & Greene, 1977; Ulrich, 1979). This is partly why it is often decided to preserve wilderness, create urban parks or generally add more vegetation to existing spaces (Driver, Rosenthal, & Petersen, 1978). These psychological benefits were researched by Ulrich (1979) when he showed participants natural views dominated by greenery, or urban views lacking vegetation or water, both scenes having equal levels of complexity. The results showed a clear pattern of restoration in the respondents who were exposed to the natural scenes. In addition, they had significantly lower anxiety levels. Conversely, the urban scenes tended to negatively affect emotional well-being. In a second study of Ulrich (1981) he recorded alpha wave amplitude, which is an indicator of cortical arousal and is connected to feelings of wakeful relaxation. He showed participants either presentations of nature with vegetation, nature with vegetation and water, or urban environments. All scenes were equal in level of complexity and information rate. The results showed that the two vegetation scenes had more positive influences on affective states. These scenes, the water scenes especially, sustained attention and interest better than the urban scenes. Alpha levels were significantly higher for the vegetation scenes too, indicating that the participants felt more wakefully relaxed in the natural environments. Thus, both studies (Ulrich, 1979; Ulrich, 1981) suggest that unspectacular natural environments positively influence restoration when compared to urban scenes. However, the researcher does note that this was measured when the participants were in an initial state of stress and excessive arousal and the results might be different for unstressed individuals.

Thus, it is theorized that exposure to unthreatening natural environments aids stress recovery and elicits positive emotional responses (Ulrich, 1983). Natural scenes should help to restore from stress by reducing negative affect, increasing positive affect, and decreasing physiological arousal. Here, restoration could also be called a 'by-product' of immediate positive affect that is elicited by the natural environment. This theory of Ulrich was eventually called the psycho-evolutionary Stress Reduction Theory. The theory has been widely used to explain preferences of natural environments and is still used until today (e.g. Jiang, He, Chen, Larsen, & Wang, 2021; Yin, Bratman, Browning, Spengler, & Olvera-Alvarez, 2022; Yao, Zhang, & Gong, 2021).

2.2 Attention Restoration Theory

Around the '80s and '90s Kaplan developed another theory that addresses the restorative effects of natural environments, called the Attention Restoration Theory (Kaplan, 1995). In this theory, as the name suggests, the concept of attention plays a central role. The work of James (1892) elaborates on directed (or voluntary) attention, which is attention that has to be used when something is important to pay attention to, but that something does not attract attention itself. Directed attention requires effort, is important in focusing, is under voluntary control, is susceptible to fatigue, and controls distractions through the use of inhibition (Kaplan, 1995). Directed attention can be fatigued when one spends mental effort on something for a prolonged amount of time. For instance, an individual that has worked intensely on a project can find themselves mentally fatigued, even though they really enjoyed the project. From evolutionary perceptive this seems logical, because paying attention to one specific thing for too long would make the individual vulnerable to threats. Being alert to the surroundings would have been a more adaptive behavior than long and intense attention to one task (Kaplan, 1995). In addition, it is argued that much of what used to be important, like wild animals, is still innately fascinating and does not require directed attention. It could very well be that directed attention fatigue is a problem of recent decades, where the gap between something that is important and that is interesting has become bigger. It could be called a large problem even, since it is said to play a key role in ineffectiveness and human error, which could even lead to accidents (Broadbent et al., 1982)

According to the Attention Restoration Theory (ART), restoration derives from recovery of directed attention fatigue (Kaplan, 1995). One way to recover could be sleeping, but this has often been proven to be insufficient. The approach that ART takes originates from the work of James (1892). Next to directed (or voluntary) attention, James also talks about involuntary attention. Involuntary attention is said to not require effort and to be resistant to fatigue. While an individual is using involuntary attention, directed attention should be able to restore. The term ‘involuntary attention’ has later been replaced by ‘fascination’, since the former was a cause of confusion in the research field (Kaplan, 1995). Fascination is best explained using some examples. It could be derived from processes, like trying to spot an unknown bird, or reading a thriller and trying to predict who committed the crime, or betting money on a certain color despite not being able to predict that color. Fascination can also be content, like the previously mentioned wild animals, or an abnormally big object. It is possible to see fascination along a soft-hard dimension. Hard fascination could be watching a car race, and soft fascination taking a walk in a park. Natural environments are typically counted as places with soft fascination and provide an additional opportunity of reflection.

Although fascination is said to be a central dimension of restoration, it is not the only necessary component. Its presence does not guarantee that directed attention can restore. Kaplan & Talbot (1983) have proposed three additional dimensions that make an environment restorative. The first dimension is ‘being away’, which can best be explained by someone freeing themselves from the mental activity that requires directed attention. This can be physically, like traveling to another place, but it can also be imaginary. Even looking at a known environment with a new perspective could give a sense of being away. The second dimension is the necessity of extent, also called ‘coherence’. This means that the environment must have enough content to be considered as a whole. That way it can engage the mind, providing enough to see and experience to take up a substantial portion of the room in someone’s head. Last, there should be ‘compatibility’ between the environment and the observer’s purposes and expectations. The setting should be fitting for what an individual is trying and wanting to do. There is no need for the individual to doubt their own behavior, because the executed behavior in the setting is appropriate.

Natural environments are argued to frequently adhere to these four dimensions (Kaplan, 1995). They are often the preferred destination for being away from the prior, mentally demanding location. However, in cities it can be quite difficult to get to the seaside or a forest for example. Fortunately, the destination does not have to be distant, or even a physical location at all. An urban park or video of a natural scene can be sufficient to create a sense of being away (Ohly et al., 2016). Additionally, fascinating contents or processes can be widely found in nature, often qualifying as soft fascination. A natural environment can also provide coherence. In a distant wilderness this is easily accomplished, but also in relatively small areas like gardens, coherence can occur. Lastly, compatibility in the natural environment is found to be particularly high. It seems as if functioning in a natural setting requires less effort than functioning in an urban setting (Cawte, 1967; Sacks, 1987).

2.3 Integration of the theories

Both Ulrich’s (1983) psycho-evolutionary Stress Reduction Theory (SRT) and Kaplan’s (1995) Attention Restoration Theory (ART) try to explain why natural environments provide restoration. However, they differ in the manner of explanation. Whereas ART is attention-oriented, SRT is stress-oriented and leaves no room for a significant role of attention. Ulrich et al. (1991) have argued that the attentional concept is not useful in explaining restoration, because they say performance deficits associated with attentional fatigue can be understood as an effect of stress. They state that it is the stress that leads to impaired cognitive performance, whereas ART states that the depletion of directed attention and the resulting mental fatigue is the cause of a stress response.

In an effort to integrate the two theories, Kaplan (1995) took a closer look into the stress response. It is generally accepted that a stress response is a human's adaptive mobilization to deal with a potentially negative situation. Kaplan (1995) proposes two major categories as leading to this adaptive mobilization; harm and resource inadequacy. Harm is often a direct occurrence that can be physically or psychologically. For instance, someone injuring themselves in a fall. Resource inadequacy is whether someone has the resources necessary to deal with situations, either happening now or anticipated. There are three subcategories of resource inadequacy. The first is appraisal, which is a deliberative process by which an individual determines if the available resources are sufficient (Lazarus, 1966). The second subcategory is a faster kind of information processing that is unlikely to be conscious. Neisser (1967) described this as intuition or a pre-attentive process. These two categories differ in consciousness and speed of processing. It is on this aspect that Kaplan (1995) claims that a part of the difference of opinion between him and Ulrich (1983) comes from. Kaplan sees a major distinction between consciousness and speed of processing, whereas Ulrich et al. (1991) does not. It is argued by Kaplan that information processing can occur rapidly and without consciousness, and thus a stress response can follow immediately. Conversely, Ulrich et al. avoid allowing information processing to play a role in the stress process. The third subcategory of resource inadequacy is the gradual depletion of some basic resource. In this case there is a reaction to the actual depletion of the resource, as opposed to the other categories where the resource inadequacy is either predicted or anticipated.

The question arises; what sort of resource might be involved in resource inadequacy? The resource has to be important to one's functioning, pervasive in its influence, and function like a resource, meaning it has to be able to deplete and subsequently influence performance. Kaplan (1995) argues that attention fits these criteria well. However, he also mentions some drawbacks of this argument. Up to then, attention has rarely been treated as a resource (Simon, 1978). The same is true for inhibitory attention and the fatigue of this mechanism. It might be for this reason that Ulrich et al. (1991) use the more mainstream terms relating to stress. In fact, Kaplan argues that a lot of the difficulty in understanding stress research is in the definition of the term 'stress'. He states that there are more studies that treat attention as a resource, but they have named it differently.

Eventually, Kaplan (1995) came up with an integrative framework where both theories fit in. The framework attempts to be inclusive to all factors that are said to lead to stress in SRT and ART. In the framework, insufficient attentional resources can be an antecedent of stress. It also incorporates anticipated resource insufficiencies and non-resource issues. In Figure 1 it is illustrated how three different patterns tend to lead to the joint presence of resource deficiencies and stress responses. In the figure, pattern A depicts a situation where resource deficiency is a precursor of stress. Pattern B shows one where stress is not resource-based, like when an individual is in pain, and this leads to resource deficiency. In pattern C, stress and resource depletion are caused simultaneously by an aversive stimulus. Overall, it can be seen that a resource decline can lead to a stress response and a stress response can lead to a resource decline. Kaplan's (1995) framework points to the existence of two distinct, but interacting, sources of restorative experiences.

Figure 1

The proposed patterns in Kaplan's integrated framework, illustrating the potential impacts of both harm and resource inadequacy

Kaplan's (1995) Integrated Framework: The Restorative Benefits of Nature

(A) Task demand ⟶ Resource decline ⟶ Stress response
⟶ Impaired performance

(B) Stress response ⟶ Severe distraction ⟶ Resource decline ⟶ Impaired performance

(C) Aversive stimulus ⟶ Resource decline ⟶ Impaired performance
Stress response

2.4 Perceived safety

One of the most basic needs for humans is safety. In Maslow's Hierarchy of Needs (1943) safety is the second most important group of needs, just after physiological needs. Safety can be divided in objective safety, such as low crime rates, and perceived safety. Perceived safety is important in itself, as feelings of insecurity can have the same effects on people as actually being at risk (Van Rijswijk, Rooks & Haans, 2016).

A lot of the research on perceived safety has its origin in Appleton's prospect-refuge theory (1975). In short, this theory states that the possibility to see (prospect) but not be seen (refuge) is basic to many biological needs. He argues that this is the result of evolution, since humans could not hunt if they were not able to see the pray, and could not survive if they were not able to hide or escape from predators. The theory not only involves landscape features, but also the amount of illumination in the environment. There can be no prospect if there is no light, and a lack of light could also offer hiding places for oneself or a predator. According to Appleton (1975), an environment elicits preference if it accommodates enough prospect and refuge.

Nonetheless, Appleton (1975) did acknowledge that there are additional environmental qualities besides prospect and refuge that influence the preference a scene elicits. Fisher, Nasar and Jones (Fisher & Nasar, 1992; Nasar & Jones, 1997) have expanded on the prospect-refuge theory, researching how subjective assessments of environmental characteristics influence the perception of that environment. First of all, Fisher and Nasar (1992) introduced the term concealment to substitute refuge, because they found the term refuge to be too ambiguous. Refuge indicates the presence of a hiding spot, but this is also where a potential predator could hide, which can make that place feel dangerous. So, they argued that concealment is a better term and said it indicates those environmental qualities that offer hiding places to potential predators. Secondly, Fisher and Nasar (1992) state that there is possibly a third factor besides prospect and concealment. This should be the ease of escape, which means there is an opportunity to flee, but also to come into contact with people that can help. To use similar terminology as for prospect and concealment, the term entrapment was introduced, which indicates those physical environmental qualities that impose a barrier to escape the environment (Nasar & Jones, 1997). This proposed framework asserts that the total of these environmental qualities are used by people to infer the safety of an environment.

But why is perceived safety important when talking about restoration? In the integrated framework of SRT and ART proposed by Kaplan (1995), it is stated that a resource deficiency can occur because of a demanding task (pattern A), a stress response (pattern B) or an aversive stimulus (pattern C). ART states that under the right circumstances, a natural environment is viewed with involuntary attention, allowing the depletion of directed attention to be restored. However, when one is feeling unsafe, intensive attention to the surroundings is needed to be ready for a possible threat. This is directed attention, since one is very aware of the situation and therefore some of the required dimensions for restoration, according to ART, cannot be met (i.e. fascination, being away and compatibility) (pattern A). On the other hand, Ulrich (1983) states in his SRT that a natural environment should be unthreatening in order to be restorative (pattern B and C). If an environment is already stressful due to perceived danger, restoration is not likely to occur. Thus, from both ART and SRT it can be argued that low perceived safety can interfere with the restorative processes proposed. However, the empirical research on this specific topic is lacking to be able to confirm these claims.

It has been researched what exact characteristics provide the right prospect, concealment and entrapment levels for an environment to be perceived as safe (Stamps, 2005). A characteristic of much interest is enclosure, which is mostly influenced by what percentage of a view is covered by regions that block motion and vision (e.g. walls, trees, etc.). In short, enclosure is the function of degree of movement through something. High levels of enclosure would be equivalent to high levels of entrapment and concealment, and low levels of prospect. Nasar et al. (1983) investigated effects of prospect and refuge by putting concrete alcoves above, behind and on the sides of participants. They also distinguished between an open view, with large distance to trees in the view, and a closed view, with small distance to the trees. This could also be seen as enclosed or non-enclosed views. They found that the open scenes were rated as safer compared to the closed scenes (Nasar et al., 1983). In addition, Stamps (2005) did four experiments on enclosure and generally concluded there to be correlations between impressions of enclosure and safety. He proposes to think of enclosure in terms of permeability, since permeability is the degree of movement through something. Subsequently, permeability can be divided into locomotive and visual permeability. Stamps (2005) found that impressions of enclosure were much more influenced by visual permeability than by locomotive permeability. However, perceived safety was much more influenced by locomotive permeability.

Another distinction in permeability is that of above and below the horizon line. In their research into perceived danger in natural environments, Lis et al. (2021) used photos where they outlined all trees and shrubs that may offer a place for concealment in an area not exceeding the height of a person. These pictures were taken from a standing position, so this area was located roughly below the line of the horizon. This method also indirectly takes into account the distance of the observer to the vegetation. As the distance to the vegetation increases, its size in the photo decreases due to perspective. The lack of prospect and presence of concealment and entrapment due to vegetation is said to negatively influence the perceived safety (Nasar & Jones, 1997). This vegetation also has an impact on locomotive permeability, which Stamps (2005) has proven to influence perceived safety. Conversely, it could be argued that permeability above the horizon line is probably not going to affect perceived safety, since this specific area is not of great importance for locomotion, and prospect, concealment and entrapment. However, the permeability above the horizon line is still an interesting aspect because of its restorative potential. More vegetation, and thus lower permeability, in this area of view could result in more restorativeness while not affecting the perceived safety.

In an effort to find other environmental characteristics that influence perceived safety, Loewen, Steel, and Suedfield (1993) asked students to list features that they believed would make an environment feel safe. The students most frequently mentioned light, open space and access to a refuge. Then the researchers investigated this quantitatively and found a correlation of light with perceived safety of .70. As previously mentioned, illumination is also a characteristic taken into account in the prospect-refuge theory. The presence of lighting can be a safety cue of itself, but it can also impact prospect, concealment and entrapment (Van Rijswijk & Haans, 2018). For instance, enough lighting can result in better visibility and therefore increase prospect and decrease concealment, which could make an environment feel safer. Van Rijswijk and Haans (2018) investigated these claims and found that perceived quality of the lighting was positively correlated with perceived environmental safety and prospect, and negatively correlated with concealment and entrapment. Furthermore, they suggest that the positive relation between lighting and perceived safety is completely accounted for by the relation between lighting and appraisals of prospect and entrapment. This indicated that there is no direct effect of lighting on perceived safety, but lighting only influences perceived safety indirectly through its effect on other environmental characteristics. Stronger evidence was found by Haans and De Kort (2012), who made their participants evaluate lighting distributions in real-life outdoor situations, rather than using measures of perceived quality. They also found that prospect, concealment and entrapment (for which they used the opposite term 'escape') were important predictors for perceived safety. Prospect was found to be the most important proximate cue, and increased as more light was being offered in the participant's immediate surroundings, instead of in more distant parts of the environment. In this experiment, the perceived safety was only partly mediated by people's appraisals of prospect, concealment and entrapment, as there was also a direct effect of light distribution. There are many other studies that have found a correlation between lighting and perceived safety without specifically investigating prospect, concealment and entrapment. Since they were probably manipulating these characteristics unintentionally, these results still hold up to the suggestions Van Rijswijk and Haans (2018), and Haans and De Kort (2012) make.

Next to its influence on perceived safety at nighttime, artificial lighting could also have a direct effect on restorativeness. Without visibility of one's surroundings restoration might be hard to achieve, but whether this can be improved with the use of artificial lighting is not a widely researched topic. A study that did investigate the effect of artificial light on restoration at nighttime was done by Nikunen and Korpela (2011). They found nighttime perceived restorativeness to be consistent with that of daytime scenes. They also found that changing the focus of the light at night can have the same effects on perceived restorativeness as physically changing the characteristics of an environment. For example, focusing the light on greenery leads to higher perceived restorativeness than focusing on car roads.

Another question is how much lighting is sufficient in order for an environment to have the right amount of prospect, concealment and entrapment, and thus be perceived as safe. An answer to this can be found in research of Boyce et al. (2000). They performed four field studies and generally found that increases in the illuminance range of 0-10 lux produce large increases in perceived safety. For increases of illuminance in the range between 10 and 50 lux there are diminishing returns. Increases above illuminances of 50 lux make little differences to perceived safety. Fotios and Castleton (2016) expand on these findings stating that for residential roads horizontal illuminances of around 3 to 5 lux result in the highest levels of perceived safety. Further increasing the illuminance has negligible benefit. This was found using the day-dark approach, which currently offers the most credible method for finding an optimum illuminance.

3. Research aim and hypotheses

The aim of this study is to investigate the environmental characteristics that influence perceived safety and perceived restorativeness in urban parks at nighttime. As previously said, urban parks are found to positively influence the health and wellbeing of their visitors (Konijnendijk et al., 2013). They often have the characteristics that are stated by SRT and ART to be restorative, such as complexity, depth, fascination and a sense of being away. However, low perceived safety is said to decrease people's willingness to go to these parks (Rahm, Sternudd, & Johansson, 2020; Lapham et al., 2016) and could possibly interfere with the restorative potential of these parks (Tabrizian et al., 2018). Thus, it is important to learn how exactly park attributes affect perceived safety and perceived restorativeness in order to find ways to improve urban parks. The focus in the current study is on the attributes permeability above horizon line, permeability below the horizon line and lighting. In this report's theoretical background some studies that focus on these aspects separately are already discussed. However, research where permeability and lighting in urban parks are studied simultaneously is more scarce. In addition, there is not much known about the factors that influence the restorativeness of natural environments at nighttime. These research gaps lead to the first two research questions:

> RQ1: To what extent do light and permeability above and below the horizon line levels influence perceived safety?
> RQ2: To what extent do light and permeability above and below the horizon line levels influence perceived restorativeness?

Subsequently, a topic of interest is how perceived safety influences the perceived restorativeness. This leads to the third research question:

> RQ3: To what extent does perceived safety influence perceived restorativeness?

These questions are answered by means of an online survey. Participants were shown walkthrough videos in which the permeability of the vegetation (e.g. trees and bushes) and illumination levels of the lanterns were varied. They had to evaluate the videos on either perceived safety or perceived restorativeness by answering rating scale questions. Due to Covid19 restrictions and uncertainties as to whether or not this study could be performed in the laboratory under controlled conditions, it was initially decided to gather participant responses through an online survey. Fortunately, the Covid19 restrictions were partly lifted and it was possible for at least some of the participant to come to the laboratory to evaluate videos. In the laboratory, it could be ensured that all participants performed the study on the same pc and computer screen and under rather similar ambient lighting conditions. In contrast, participants in the online version, most likely answered the survey questions on a variety of different devices and in widely different environmental conditions. This made it interesting to compare the results obtained in the laboratory with those from the online survey.

Regarding RQ1, it is expected that permeability below the horizon line and lighting intensity positively influence perceived safety. The increased visibility resulting from more permeability and more lighting should increase the levels of prospect and decrease the levels of concealment and entrapment. Multiple aforementioned studies suggest that this should lead to increased perceived safety (Fisher & Nasar, 1992; Nasar & Jones, 1997; Haans & De Kort, 2012; Van Rijswijk & Haans, 2018). The current study argues that the permeability above the horizon line does not have a significant effect on perceived safety, because this area of one's vision is not likely to affect locomotive permeability and the levels of prospect, concealment and entrapment.

As for RQ2, the expected effect of permeability is more ambiguous. When looking at SRT it could be argued that decreasing the permeability is beneficial because it could create more complexity and depth cues. However, a view that is too impenetrable does not have proper depth, which lowers the chances of restoration (Ulrich, 1983). So, this study hypothesizes that the effect of permeability, both above and below the horizon line, on perceived restorativeness would be an inverted U-shape; low permeability results in low perceived restorativeness, moderate permeability gives high perceived restorativeness, and high permeability yields low perceived restorativeness. This complies with what was found by Jiang, Chang and Sullivan (2014) when they researched the relation between the density of tree cover and stress reduction. Regarding the effect of lighting on perceived restorativeness the expectation is relatively straightforward: In accordance with the findings of Nikunen and Korpela (2011) it is expected that lighting positively influences perceived restorativeness due to increased visibility of the restorativeness characteristics. Especially since the lanterns in the videos are located at the sides of the road, shedding light on the bushes and trees located nearby.

The expected finding for RQ3 is that perceived safety positively influences perceived restorativeness. As previously argued, low perceived safety could interfere with the restorative process. According to SRT this is because threatening situations elicit negative affect and therefore restoration will not be possible (Ulrich, 1983). ART states that indirect attention is necessary in order for restoration of directed attention to occur (Kaplan, 1995). However, this study argues that low perceived safety demands directed attention, which means that this resource cannot be restored.

4. Method

In this part of the report the method of the performed experiment is explained. This includes the design, participants, materials, procedure, measurements and data analysis.

4.1 Design

In this study a 3x3x3 within-subject experiment with perceived restorativeness and perceived safety as dependent variables was conducted. Participants had to fill in a survey where they evaluated walkthrough videos of different park designs. The three manipulated variables were permeability above the horizon line, permeability below the horizon line and lighting. The number of video alternatives was limited to nine (Table 1), using an orthogonal array (also known as a Taguchi design). This design is primarily intended to study main effects and not the interactions between factors, because such interactions are confounded and cannot be assessed separately.

The values of the permeability variables resulted from varying the amount of trees and bushes in the videos, and was measured by how much of the view was unobstructed (in percentages). This means that a higher percentage is equivalent to more permeability. For the permeability above the horizon line these percentages were 5%, 30% and 60%. Below the horizon line they were higher; 60%, 70% and 85%. This difference between the two variables has to do with the relatively straight path in the middle of the view below the horizon line, which automatically provided unobstructed sight into the distance. The illuminance values of the lighting were 1, 3 and 5 lux. This is based on the previous mentioned study of Fotios and Castleton (2016), which stated that the optimal illuminance for perceived safety is 3-5 lux. The color of the lights was 3000K, because this is a regular color temperature for park lighting, which limits the extent of negative ecological impact (RASC, 2018).

Participants were randomly assigned to one of two groups which either evaluated the videos on perceived safety or perceived restorativeness. This was done to avoid a spurious correlation between the two estimates, which can appear due to common method bias (Van Rijswijk & Haans, 2017). This bias can occur when both dependent variables are measured within one survey, using the same measurement technique (Kock, Berbekova, & Assaf, 2021). In that case, the supposed correlation between the dependent variables might in reality be attributed to the common method that was used, instead of the variables themselves (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003).

Furthermore, the participants could either fill in the survey in a laboratory setting provided by the experimenters or online on their own devices. Due to uncertainties as to whether it would be possible to perform the survey in a controlled laboratory setting because of Covid19 restrictions, it was initially decided that the survey would be entirely performed online. Fortunately, part of the restriction were lifted and it became possible for some of the participants to make the survey in the laboratory. In the laboratory, it could be ensured that all participants performed the study on the same pc and computer screens, under similar ambient lighting conditions. Conversely, the participants that made the survey online most likely answered the question on a variety of different devices and in different environmental conditions. This brought the opportunity to investigate possible differences between the two settings.

The videos showed non-immersive virtual reality (VR) environments. Research has shown that responses to a non-immersive VR environment are comparable to those induced by a real environment (Higuera-Trujillo et al., 2017). Non-immersive VR environments are evaluated as a realistic representation of the real world (Bishop & Rohrman, 2003). Although people feel more present in the environment when using immersive VR, non-immersive VR is less time-consuming and can be incorporated in an online survey. The study was approved by the ethical review board of Eindhoven University of Technology (experiment number: 1467).

Table 1

Nine alternative park designs and their corresponding attribute levels following a Taguchi design

Alternative	Permeability above horizon line	Permeability below horizon line	Lighting
1	60%	85%	1 lux
2	60%	70%	3 lux
3	60%	60%	5 lux
4	30%	85%	3 lux
5	30%	70%	5 lux
6	30%	60%	1 lux
7	5%	85%	5 lux
8	5%	70%	1 lux
9	5%	60%	3 lux

4.2 Participants

118 people participated in this study (61 males, 56 females and 1 gender-neutral, M_{age} = 24.8, SD_{age}= 9.0, age range = 18-59). Of this number 41 made the survey in a controlled laboratory setting provided by the experimenters. The remaining 77 made it online on their own devices in a setting of their choosing. 65 of the participants reported high school as their highest level of finished education, the remaining 53 finished further education. However, it has to be noted that a lot of the participants were currently receiving bachelor education. Of the participants, 81 lived in a city and 36 lived in a town, village or in the countryside. Lastly, 60 participants reported to visit a park (on average) once a month or less, and 56 reported visiting more than once a month.

Participants of the controlled laboratory setting were registered in the JSF Schouten participant database at Eindhoven University of Technology (TU/e). They received 5 euros (plus an additional 2 euros if they did not attend the TU/e or Fontys Eindhoven) as compensation for their time and effort. The online participants were also recruited through the database or through the experimenter's personal network and had a 20% chance to win 20 euros if they chose to participate in a raffle.

As previously mentioned, the participants were randomly assigned to one of two groups. The first group consisted of 60 participants (28 males, 31 females and 1 gender-neutral, M_{age} = 25.0, SD_{age}= 9.8, age range = 18-59) and evaluated the videos on perceived restorativeness. The second group consisted of 58 participants (33 males and 25 females, M_{age} = 24.6, SD_{age}= 8.1, age range = 18-58) and evaluated the videos on perceived safety.

4.3 Materials

The survey was created in Limesurvey. In this program the order of the video alternatives, as well as the assignment to one of the two groups (perceived safety or perceived restorativeness), could be randomized. The virtual park was created using SketchUp 2018 and Twinmotion EDU 2021.1.4, and was based on the videos in the study of Van Vliet et al. (2020). The base of the park was created in SketchUp and consisted of around 3.5 hectares, surrounded by roads, houses, and apartment blocks (Figure 2). The surface materials, vegetation (bushes and trees) and lighting were added in Twinmotion. Here, the environment's geographic location was the same coordinates as Eindhoven, The Netherlands. The time and weather was set to 11:00 PM in August with a little cloud cover. Multiple scenes with different amounts of vegetation and lighting were created in order to easily vary the variables in each alternative. For each alternative a video of around 20 seconds was exported, which simulated a walk through the south part of the park. The resulting nine videos were uploaded to Youtube and embedded in Limesurvey. In Figure 3 the top views of a selection of alternatives is shown at 2:00 PM.

Figure 2

Top view image of the base park during daytime

Figure 3

Top view images of video alternatives 1, 5 and 9 during daytime with the amount of permeability above and below the horizon line described underneath

Alternative 1 (60% permeability above horizon line, 85% permeability below horizon line)

Alternative 5 (30% permeability above horizon line, 70% permeability below horizon line)

Alternative 9 (5% permeability above horizon line, 60% permeability below horizon line)

The permeability variables were determined by measuring the percentage of view that was unobstructed for both below and above the horizon line. Per condition four pictures, spread over the duration of the videos, were exported. Using the histogram function of Adobe Photoshop 2018, the unobstructed view was selected and the amount of pixels was calculated per picture (Figure 4). The average percentages for permeability below the horizon line were set to be 60%, 70% and 85%, and for permeability above the horizon line 5%, 30% and 60%. These percentages were chosen by looking at how realistic the environment looked and also because the increase in permeability across the consecutive levels is relatively even.

Figure 4

Image of an example of the measurement method for permeability above (30%) and below (70%) the horizon line (depicted at daytime for sufficient visibility)

Note. The red line indicates the border between above and below the horizon line. The area that was counted as unobstructed view is the area that is not colored grey, which was used as the value for permeability.

The lighting conditions were set to 1, 3 and 5 lux, which came from Twinmotion's spot lights installed in the street lanterns (called Streamlined). The spot lights were located 3.5m from the ground with 50 (1 lux), 100 (3 lux) and 200 (5 lux) lumen shining from them. The lights were positioned on both sides of the paths with a distance of around 10m in between. In Figure 5 the three lighting conditions are shown when the permeability above the horizon line was 30% and below the horizon line was 70%. Figure 6 shows images of alternatives 1, 5 and 9 with their corresponding levels of light and permeability above and below the horizon line (images of all video alternatives can be seen in Appendix A).

Figure 5

Eye-height images of the three light conditions during nighttime (1, 3 and 5 lux) with 30% permeability above the horizon line and 70% permeability below the horizon line

Alternative with 1 lux

Alternative with 3 lux

Alternative with 5 lux

Figure 6

Eye-height images of alternative 1, 5 and 9 with the amount of permeability above and below the horizon line and light described beneath them

Alternative 1 (60% permeability above horizon line, 85% permeability below horizon line, 1 lux light)

Alternative 5 (30% permeability above horizon line, 70% permeability below horizon line, 5 lux light)

Alternative 9 (5% permeability above horizon line, 60% permeability below horizon line, 3 lux light)

In the laboratory setting, participants made the survey in one of three cubicles. Here, the room lighting was set to the lowest level, resulting in a horizontal illuminance range from 78 to 100 lux measured on the desk and a vertical illuminance from 70 to 85 lux measured on the wall above the screen. The screens were HP EliteDisplay E240c displays which were calibrated using the Datacolor Spyder 3 Elite v4.0.

4.4 Procedure

Participants that made the on campus version of the survey were expected at the Psychology lab on the ninth floor of the TU/e Atlas building. Here, they were welcomed in from the waiting space and taken to a computer to register in the participant database, read and sign the informed consent form and fill in a Covid logbook. Then, they were guided to one of the three available cubicles. The experimenter briefly instructed the participants not to touch the screen or light settings and left them to fill in the survey. First, a short explanation text was shown; “In the next part of the survey you will be shown nine walkthrough videos of different park settings. Please watch these completely and answer the questions underneath each one of them. Imagine that you are the person that is walking through the parks. You can start the videos by clicking the 'play' button.” After reading this, the participants could continue and the first video was displayed in the middle of the screen with the corresponding questions beneath it. In this manner they evaluated all nine videos. If necessary, it was possible to go to previous videos to change answers. After answering all questions about the videos, some demographical questions were asked about gender, age, education, living area and how often they visit parks. There was some room to leave remarks after this. When completed, the survey could be submitted and the participants were thanked for their participation and received money as a compensation for their time.

The online version could be completed by clicking the survey link on one’s computer at any time they preferred. The online version had some small differences compared to the content of the on-campus survey. Two questions were added; a digital consent form and a question about whether they wanted to participate in a raffle with the chance to win 20 euros for their participation. In addition, the explanation was expanded with instructions to put the videos on the highest resolution possible, put their screen on the highest brightness and turn off any screen altering settings.

4.5 Measurements

Perceived restorativeness was measured using the perceived restorativeness scale (PRS) of Hartig et al. (1997a). This scale is based on the Attention Restoration Theory and its four dimensions. The original has 26 items, but many studies have also used shortened versions (Negrin et al., 2017; Nikunen et al., 2014; Pasini at al., 2014). As 26 items per video would take a long time to answer, a selection in items was made. First, the items regarding the compatibility dimension were excluded. This dimension is about the fit between the environment's attributes and the individual’s purposes and expectations. Since the participants do not have any pre-set goals or expectations of the shown videos beforehand and this is also hard to convey through videos, this dimension was dropped. Then, the three questions with the highest factor loadings per remaining dimension (being away, fascination and coherence) were selected (Hartig et al., 1997b). This resulted in a scale composed of the following nine items: “Being here is an escape experience”; “Spending time here gives me a break from my day-to-day routine”; “This is a place to get away from it all”; “This place has fascinating qualities”; “My attention is drawn to many interesting things”; “I want to get to know this place better”; “This is a confusing place” (recoded); “There is a great deal of distraction here” (recoded); and “It is chaotic here” (recoded). Participants rated these items on a 5-point scale ranging from “Strongly disagree” (coded with a 1) to “Strongly agree” (coded with a 5). In addition, there was an option to not answer a question by filling in “No answer”. If this option was chosen, the answer was treated as a missing answer. For the first item, “Being here is an escape experience”, this resulted in 29 missing answers and for the remaining eight items in around 10 missings each.

Perceived safety was measured using an adapted version of Blöbaum and Hunecke’s perceived personal danger scale (2005). This scale consisted of the following seven statements: “I would not mind to walk along this place unaccompanied”; “I would take a long detour to avoid this place” (recoded); “I would quickly get away from this place” (recoded); “I would have an unpleasant feeling in this place” (recoded); “I would feel uneasy in this place” (recoded); “I would feel safe in this place”; and “I would feel anxious in this place” (recoded). The same answer options as for the PRS were given. The option “No answer” was treated as a missing answer again. All questions on perceived safety had either zero or one missing answer.

The demographical questions and their answering options included: “What is your gender?” with the possibilities female, male and gender-neutral; “What is your age?” where a number could be entered;

“What is the highest level of education you have completed?” with the possibilities high school, secondary vocational education (MBO), university of applied sciences (HBO), WO bachelor, WO master and PhD; “Where do you currently live?” with the possibilities in the countryside, village, town or city; and “How often do you visit a park (on average)?” with the possibilities never, once a year, few times a year, once a month, once every two weeks, once every week and multiple times a week. All questions besides age also had the options prefer not to say and other, the latter gave the possibility to fill in something different. A complete version of the survey can be found in Appendix B.

4.6 Data analysis

The data analysis was performed in several steps using STATA 17.0. First, the data was cleaned and preparations for analysis were made, including the creation of two separate variables for the perceived safety scores and the perceived restorativeness scores. Second, the descriptive statistics were calculated per measurement group (safety or restorativeness). Then, potential differences between the laboratory and the online version of the survey were investigated (called the laboratory-online variable from here on). This was done through visual inspection of boxplots of the perceived safety and perceived restorativeness scales, and by performing an ANOVA analysis were the video variable (video alternative 1 to 9) was added as a repeated measure. If the analyses showed a significant difference between the laboratory and online setting, this variable would be included in the following analyses.

The next step was to construct multi-level models nested within participant number. These models were built up by adding more and more variables to an empty model. The first series of models measured the effects on perceived safety of the main variables, the laboratory-online variable and the interactions between the main variables and the laboratory-online variable (RQ1). For the categorical main variables dummy coding was used to measure the effect of their three categories separately. The next series of models consisted of the same predictor variables, but measured the effects on perceived restorativeness (RQ2).

To investigate the influence of perceived safety on perceived restorativeness (RQ3) a new variable consisting of the average values for perceived safety per video was created. This variable was then included in the multi-level models on perceived restorativeness.

Lastly, with the use of multi-level models, it was investigated whether the demographical variables had any influence on perceived safety and perceived restorativeness.

5. Results

In this next section the results of the analyses are discussed. This includes the descriptive statistics, the influence of the setting, and several multi-level models on perceived safety and perceived restorativeness.

5.1 Descriptive statistics

Two participants were removed from the dataset, because they only answered the questions for a few videos. In Table 2 the descriptive statistics of the remaining 118 participants are shown divided by perceived safety or perceived restorativeness. There was one participant who reported to identify as gender-neutral. Since no analyses can be done on such a small number, this answer was excluded from further analyses.

Table 2

Descriptive statistics of the participants

	Perceived safety	Perceived restorativeness
Participants (N)	58	60
Survey version (N)		
Laboratory	17	24
Online	41	36
Gender (N)		
Female	25	31
Male	33	28
Gender-neutral	0	1
Age (years)		
Mean	24.6	25.0
Standard deviation	8.1	9.8
Range	18-58	18-59
Education (N)		
High school	27	38
Further education	31	22
Living place (N)		
Countryside/village/town	19	17
City	39	42
No answer	0	1
Park visits (N)		
Once a month or less	28	32
More than once a month	29	27
No answer	1	1

Before creating the scale scores for perceived safety and perceived restorativeness, it was tested whether all items were appropriate to measure their corresponding topic. This was done by checking if the reliability of the scales (i.e. Cronbach's alpha) improved when items were added or excluded. For both perceived safety and perceived restorativeness the reliability was highest when all items were included. Subsequently, the scales were created by averaging the mean ratings of all corresponding items. The resulting scale reliability for perceived restorativeness was acceptable (Cronbach's alpha between 0.7 and 0.8) and for perceived safety was excellent (Cronbach's alpha higher than 0.9). The sample statistics of the two scale scores are shown in Table 3.

Table 3

Perceived safety and perceived restorativeness scale statistics and Cronbach's alpha

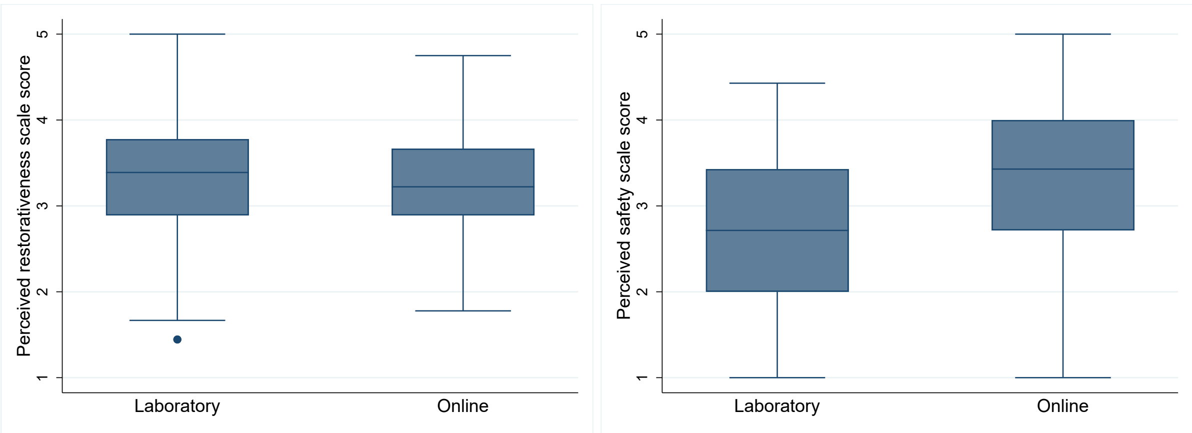
	Mean	Standard Deviation	Min	Max	Cronbach's alpha
Perceived safety	3.15	0.92	1	5	0.94
Perceived restorativeness	3.29	0.59	1.44	5	0.75

5.2 The influence of the survey setting

To see if it made any difference whether the participants performed the survey in the laboratory or online some exploratory analyses were done. In Figure 7 two box plots are shown of the perceived safety and perceived restorativeness scales over the laboratory-online variable. Through a visual inspection of the plots it could be seen that there was not much difference in perceived restorativeness. However, there did seem to be a difference in perceived safety. To confirm this, a multiple factor ANOVA analysis repeated over the video variable (i.e. video alternative 1 to 9) was performed. This showed that the laboratory-online variable indeed had an insignificant effect on perceived restorativeness ($F(1, 75) = 0.51$, $p = 0.476$) and a significant effect on perceived safety ($F(1, 73) = 10.62$, $p = 0.002$). As a consequence, the laboratory-online variable was included in the successive multi-level models.

Figure 7

Box plots of the perceived restorativeness (N=60) and perceived safety (N=58) scale scores separated by laboratory-online



5.3 Multi-level models on perceived safety

For the next part of the analysis, four multi-level models nested within participants were created. In these models, perceived safety was the dependent variable and permeability above and below the horizon line, light, laboratory-online and the interactions between the main variables and laboratory-online were added as the independent variables in a stepwise manner. The resulting estimates and standard errors of the four models can be seen in Table 4.

The first model was an empty model with solely perceived safety as dependent variable and no other variables included, measuring the variance at the level of the individual. The model showed that about half (52%) of the variance could be attributed to the level of the individual and the other half to the characteristics of the environments depicted in the videos.

It can be seen that in model 1, 2 and 3, both categories of permeability above the horizon line (30% and 60%) had a positive significant effect relative to the 5% category (in model 3 respectively, $\beta = 0.398$, $p < 0.001$, and $\beta = 0.704$, $p < 0.001$). Since the estimate of 60% permeability was bigger than that of 30%, it can be stated that perceived safety increased as the permeability became higher. Regarding permeability below the horizon line, it can be seen that in model 1 and 2 the permeability of 85% had a significant effect on perceived safety relative to the reference level of 60% permeability ($\beta = 0.155$, $p = 0.008$). However, in model 3, when the laboratory-online interactions were added, the effect was not significant anymore. In model 3, the reference category for the main variables was the laboratory setting. This could suggest that the significant effects of 85% permeability below the horizon line in model 1 and 2 were there because they were significant in the online setting.

In all models where lighting was included, the illumination levels 3 and 5 lux had a significant positive effect on perceived safety relative to the 1 lux level (in model 3 respectively, $\beta = 0.251$, $p = 0.018$, and $\beta = 0.671$, $p < 0.001$). Here, the same can be stated as for permeability above the horizon line; since the estimate of 5 lux was bigger than that of 3 lux, perceived safety increased as the light levels increased. In Figure 8 a graph of all significant estimates of the main predictors is shown.

Starting from model 2, the laboratory-online variable was added, which indicated whether the participant made the survey in the laboratory or on their own device online. Model 2 and 3 both showed that making the survey online instead of in the laboratory had a positive significant effect on perceived safety (in model 3: $\beta = 0.674$, $p =0.003$).

Next, interactions with the laboratory-online variable were tested. The results of model 3 indicate that there were two significant interactions. The first was an interaction with permeability below the horizon line. In the online version, participants reported higher perceived safety when the permeability was 70% than in the laboratory setting ($\beta = 0.277$, $p = 0.028$). The second significant effect was the interaction with light of 5 lux ($\beta = -0.275$, $p = 0.029$). This indicated that making the survey online instead of in the laboratory resulted in lower perceived safety scores when the light level was 5 lux. At the same time, the lighting still had a positive effect on perceived safety, regardless of the place participants made the survey ($\beta = 0.671-0.275 = 0.415$), thus the direction of the effect did not change. So, whereas a higher level of lighting has a positive effect on perceived safety, this effect was smaller when the survey was made online.

Table 4

Overview of the predictor estimates of four multi-level models on perceived safety

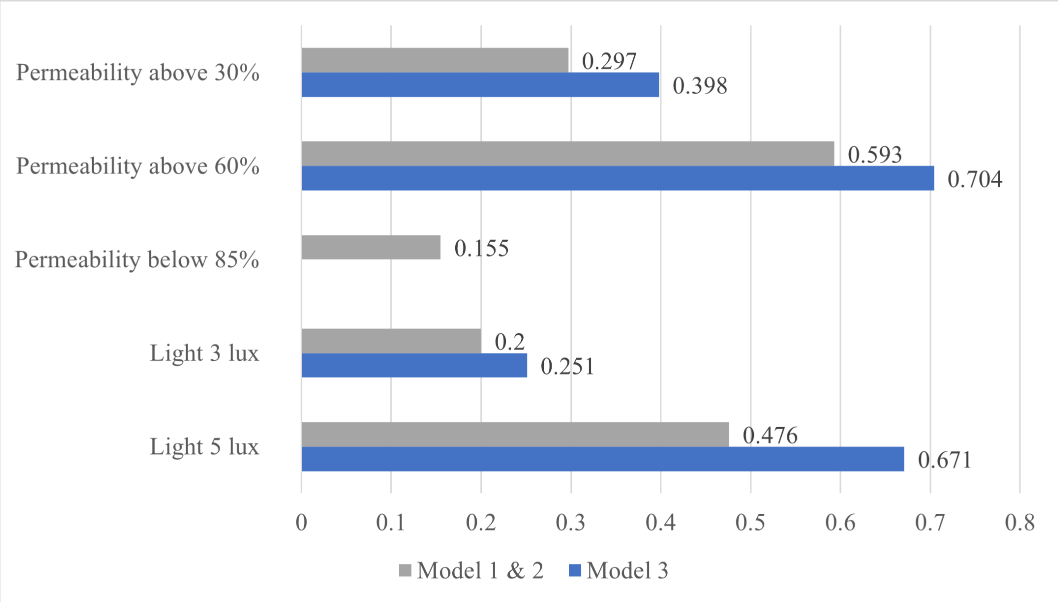
Predictor	Empty model	Model 1	Model 2	Model 3
Permeability above 5%		0	0	0
		(.)	(.)	(.)
Permeability above 30%		0.297**	0.297**	0.398**
		(0.058)	(0.058)	(0.106)
Permeability above 60%		0.593**	0.593**	0.704**
		(0.058)	(0.058)	(0.106)
Permeability below 60%		0	0	0
		(.)	(.)	(.)
Permeability below 70%		0.067	0.067	-0.129
		(0.058)	(0.058)	(0.106)
Permeability below 85%		0.155*	0.155*	0.021
		(0.058)	(0.058)	(0.106)
Light 1 lux		0	0	0
		(.)	(.)	(.)

Light 3 lux		0.200**	0.200**	0.251*
		(0.058)	(0.058)	(0.106)
Light 5 lux		0.476**	0.476**	0.671**
		(0.058)	(0.058)	(0.106)
Lab			0	0
			(.)	(.)
Online			0.615**	0.674*
			(0.185)	(0.224)
Permeability above 5% # Lab				0
				(.)
Permeability above 30% # Online				-0.143
				(0.126)
Permeability above 60% # Online				-0.157
				(0.126)
Permeability below 60% # Lab				0
				(.)
Permeability below 70% # Online				0.277*
				(0.126)
Permeability below 85% # Online				0.190
				(0.126)
Light 1 lux # Lab				0
				(.)
Light 3 lux # Online				-0.071
				(0.126)
Light 5 lux # Online				-0.275*
				(0.126)
Constant	3.152**	2.556**	2.121**	2.079**
	(0.092)	(0.109)	(0.166)	(0.189)
var(constant)	0.446	0.458	0.380	0.381
	(0.091)	(0.091)	(0.077)	(0.077)
var(residual)	0.408	0.295	0.295	0.287
	(0.027)	(0.019)	(0.019)	(0.019)
Observations	522	522	522	522

Note. Standard errors in parentheses
* $p < 0.05$, ** $p < 0.001$

Figure 8

Graph of the significant main effects on perceived safety per model (1&2, and 3)



Note. Reference variable categories: permeability above 5%, permeability below 60% and light 1 lux

5.4 Multi-level models on perceived restorativeness

In the next part of the analysis, similar models were created but this time with perceived restorativeness as the dependent variable. Again, the empty model was used to measure the variance on the participant level, which was 47%. The estimates of the four models can be found in Table 5.

In model 1, 2, and 3 it can be seen that the permeabilities above the horizon line had a significant effect on perceived restorativeness. For model 3, the 30% permeability level had a significant positive effect of $\beta = 0.178$ ($p = 0.009$), and 60% permeability had an effect of $\beta = 0.282$ ($p < 0.001$) relative to 5% permeability. This means that increased permeability above the horizon line positively influenced perceived restorativeness. For permeability below the horizon line all models showed that this independent variable had no significant effects on perceived restorativeness. These results contradict the hypothesis of the effect of both permeabilities on perceived restorativeness being an inverted U-shape. Instead, they suggest that permeability above the horizon line has a linear effect on perceived restorativeness, and permeability below the horizon line has no effect at all.

Both light levels of 3 and 5 lux are shown to have a positive effect on perceived restorativeness in model 1, 2 and 3 (in model 3 respectively, $\beta = 0.297$, $p <0.001$, and $\beta = 0.274$, $p < 0.001$). The estimate of 3 lux was larger than the 5 lux level, indicating that a higher illumination level was not equal to higher levels of perceived restorativeness (i.e. non-linear). Since the difference between the estimates was quite small, it could be said that the effects of 3 and 5 lux are similar, with only a slight favor for the 3 lux level. This would mean that an amount of 3 lux is already sufficient to increase the perceived restorativeness levels in urban parks. In Figure 9 a graph of the significant estimates of the main predictors is shown.

Next, the effects of laboratory-online and its interactions with the main variables were tested. Models 2 and 3 showed that the laboratory-online variable had no significant effects. Conversely, as can be seen in model 3, the interactions of laboratory-online with light did produce significant effects. Participants who made the survey online reported lower perceived restorativeness compared to those who made it in the laboratory for both the 3 and 5 lux levels (respectively, β = -0.316, p < 0.001, and β = -0.287, p = 0.001). In fact, these estimates were large enough to reverse the direction of the main effects of light (3 lux: β = 0.297-0.316 = -0.019 , and 5 lux: β = 0.274-0.287 = -0.013). Thus, the effects of 3 and 5 lux lighting diminished when participants made the survey online instead of in the laboratory. This effect of survey setting on light could also be seen when a multi-level model of the main predictors with only laboratory participants, and another one with only online participants were created. In the model with laboratory participants the effects of 3 and 5 lux were positively significant (respectively, β = 0.297, p < 0.001, and β = 0.274, p < 0.001), whereas these effects were very small and insignificant in the model with online participants (respectively, β = -0.019, p = 0.708, and β = -0.013, p = 0.805).

Table 5

Overview of the predictor estimates of four multi-level models on perceived restorativeness

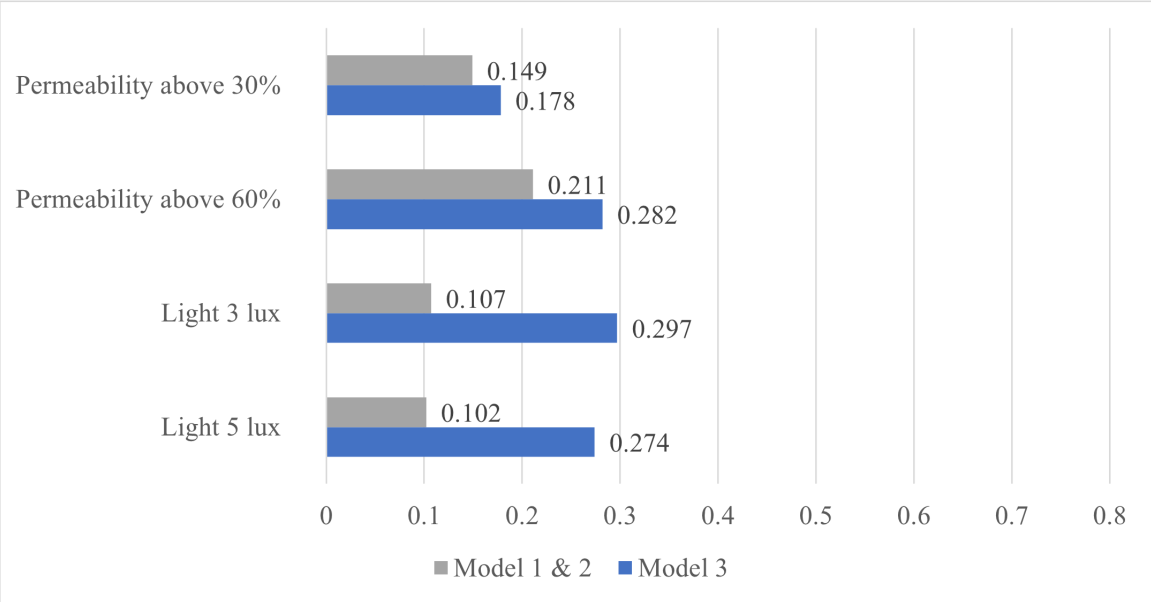
Predictor	Empty model	Model 1	Model 2	Model 3
Permeability above 5%		0 (.)	0 (.)	0 (.)
Permeability above 30%		0.149** (0.044)	0.149** (0.044)	0.178* (0.068)
Permeability above 60%		0.211** (0.044)	0.211** (0.044)	0.282** (0.068)
Permeability below 60%		0 (.)	0 (.)	0 (.)
Permeability below 70%		0.008 (0.044)	0.008 (0.044)	0.040 (0.068)
Permeability below 85%		0.030 (0.044)	0.030 (0.044)	0.075 (0.068)
Light 1 lux		0 (.)	0 (.)	0 (.)
Light 3 lux		0.107* (0.044)	0.107* (0.044)	0.297** (0.068)
Light 5 lux		0.102* (0.044)	0.102* (0.044)	0.274** (0.068)
Lab			0 (.)	0 (.)
Online			-0.083 (0.113)	0.216 (0.143)
Permeability above 5% # Lab				0 (.)
Permeability above 30% # Online				-0.049 (0.088)
Permeability above 60% # Online				-0.118 (0.088)
Permeability below 60% # Lab				0 (.)
Permeability below 70% # Online				-0.052 (0.088)
Permeability below 85% # Online				-0.076 (0.088)
Light 1 lux # Lab				0 (.)
Light 3 lux # Online				-0.316** (0.088)

Light 5 lux # Online				-0.287*
				(0.088)
Constant	3.294**	3.092**	3.141**	2.962**
	(0.056)	(0.071)	(0.098)	(0.111)
var(constant)	0.166	0.167	0.165	0.166
	(0.034)	(0.034)	(0.034)	(0.034)
var(residual)	0.185	0.173	0.173	0.167
	(0.012)	(0.011)	(0.011)	(0.011)
Observations	540	540	540	540

Note. Standard errors in parentheses
* $p < 0.05$, ** $p < 0.001$

Figure 9

Graph of the significant main effects on perceived restorativeness per model (1&2, and 3)



Note. Reference variable categories: permeability above 5%, permeability below 60% and light 1 lux

5.5 Multi-level models on perceived restorativeness with perceived safety as predictor

The next series of models was almost the same as the previous models on perceived restorativeness. The only difference is that there was no empty model, but instead the average perceived safety per video was added as predictor to all models. This way the effect of perceived safety on perceived restorativeness could be measured. In Table 6 the estimates of the four resulting models can be seen.

First of all, adding perceived safety as a predictor resulted in mixed results between the models. In model 1, where it was the only predictor, perceived safety had a positive effect on perceived restorativeness ($\beta = 0.289$, $p < 0.001$). This means that as the perceived safety scores increased, the reported perceived restorativeness also increased. However, in the models 2, 3 and 4, where the other variables were included, perceived safety did not have a significant effect anymore.

Regarding permeability above the horizon line, permeability below the horizon line and light, it can be seen that none of these variables had any significant effects on perceived restorativeness. Adding these variables to the models even resulted in the perceived safety estimates becoming negative, although not significant. The three main variables might have accounted for the effect of perceived safety on perceived restorativeness. Thus, the significant positive effect of perceived safety in model 1 could be explained by the main variables that were added later on and vice versa. The results suggest large multicollinearity between perceived safety and the main predictors, which is also indicated by the large standard errors of especially the perceived safety variable.

Lastly, the laboratory-online variable and its interactions with the main variables were tested. As can be seen in Table 5 and 6, both series of models gave exactly the same results for any predictor involving laboratory-online. This indicates that adding perceived safety to these models did not affect these predictors in any way.

Table 6

Overview of the predictor estimates, including average perceived safety per video, of four multi-level models on perceived restorativeness

Predictor	Model 1	Model 2	Model 3	Model 4
Average perceived safety per video	0.289**	-2.497	-2.497	-2.497
	(0.057)	(2.082)	(2.082)	(2.043)
Permeability above 5%		0	0	0
		(.)	(.)	(.)
Permeability above 30%		0.890	0.890	0.919
		(0.620)	(0.620)	(0.610)
Permeability above 60%		1.693	1.693	1.763
		(1.236)	(1.236)	(1.214)
Permeability below 60%		0	0	0
		(.)	(.)	(.)
Permeability below 70%		0.175	0.175	0.207
		(0.147)	(0.147)	(0.153)
Permeability below 85%		0.417	0.417	0.463
		(0.326)	(0.326)	(0.325)
Light 1 lux		0	0	0
		(.)	(.)	(.)
Light 3 lux		0.608	0.608	0.798
		(0.420)	(0.420)	(0.415)
Light 5 lux		1.292	1.292	1.464
		(0.993)	(0.993)	(0.976)
Lab			0	0
			(.)	(.)
Online			-0.083	0.216
			(0.113)	(0.143)
Permeability above 5% # Lab				0
				(.)
Permeability above 30% # Online				-0.049
				(0.088)
Permeability above 60% # Online				-0.118
				(0.088)
Permeability below 60% # Lab				0
				(.)
Permeability below 70% # Online				-0.052
				(0.088)
Permeability below 85% # Online				-0.076
				(0.088)

Light 1 lux # Lab				0
				(.)
Light 3 lux # Online				-0.316**
				(0.0877)
Light 5 lux # Online				-0.287*
				(0.088)
Constant	2.384**	9.474	9.524	9.344
	(0.187)	(5.322)	(5.322)	(5.223)
var(constant)	0.167	0.167	0.166	0.166
	(0.034)	(0.034)	(0.034)	(0.034)
var(residual)	0.175	0.173	0.173	0.166
	(0.011)	(0.011)	(0.011)	(0.011)
Observations	540	540	540	540

Note. Standard errors in parentheses
* $p < 0.05$, ** $p < 0.001$

5.6 The influence of gender on perceived safety and perceived restorativeness

Lastly, an exploratory analysis of the effects of demographical variables was done. After running several models with all demographic variables included, it turned out that gender was the most interesting variable. The other ones were either not evenly divided enough (i.e. age) or yielded insignificant results. Therefore, another two multi-level models were constructed, one on perceived safety and one on perceived restorativeness. This time the included predictors were the main variables, laboratory-online, gender, and the interactions between gender and the other variables. The resulting two models can be seen in Table 7.

In the model on perceived safety, gender had a significant effect (β = 0.754, p = 0.008), meaning that males reported higher perceived safety than females. The only significant gender interaction was with light of 5 lux (β = -0.453, p < 0.001), which meant that males reported lower perceived safety than females in the 5 lux light condition. Since the main effect of 5 lux light was positive and quite large (β = 0.734, p < 0.001), the effect of this light level was still positive for males (β = 0.734-0.453 = 0.281). Furthermore, it can be seen that all levels of permeability above the horizon line and light were still positively significant, just as in section 5.3 (Table 4).

In the perceived restorativeness model, gender did not have a significant effect, but the interaction of gender with laboratory-online did. Compared to females, males reported lower perceived restorativeness when they made the survey online (β = -0.624, p = 0.004). In addition, the main variables permeability above the horizon line and light had a significant positive effect on perceived restorativeness.

Table 7

Overview of the predictor estimates, including the main variables, laboratory-online, gender, and gender interactions, of two multi-level models on perceived safety and perceived restorativeness.

Predictor	Perceived Safety	Perceived Restorativeness
Permeability above 5%	0	0
	(.)	(.)
Permeability above 30%	0.295**	0.166*
	(0.087)	(0.061)
Permeability above 60%	0.538**	0.234**
	(0.087)	(0.061)

Permeability below 60%	0	0
	(.)	(.)
Permeability below 70%	0.055	0.009
	(0.087)	(0.061)
Permeability below 85%	0.092	0.051
	(0.087)	(0.061)
Light 1 lux	0	0
	(.)	(.)
Light 3 lux	0.188*	0.144*
	(0.087)	(0.061)
Light 5 lux	0.734**	0.190*
	(0.087)	(0.061)
Lab	0	0
	(.)	(.)
Online	0.390	0.207
	(0.214)	(0.143)
Female	0	0
	(.)	(.)
Male	0.754*	0.349
	(0.282)	(0.193)
Permeability above 5% # Female	0	0
	(.)	(.)
Permeability above 30% # Male	0.003	-0.043
	(0.115)	(0.088)
Permeability above 60% # Male	0.097	-0.038
	(0.115)	(0.088)
Permeability below 60% # Female	0	0
	(.)	(.)
Permeability below 70% # Male	0.022	-0.002
	(0.115)	(0.088)
Permeability below 85% # Male	0.111	-0.027
	(0.115)	(0.088)
Light 1 lux # Female	0	0
	(.)	(.)
Light 3 lux # Male	0.023	-0.076
	(0.115)	(0.088)
Light 5 lux # Male	-0.453**	-0.166
	(0.115)	(0.088)
Lab # Female	0	0
	(.)	(.)
Online # Male	0.113	-0.624*
	(0.309)	(0.219)
Constant	1.800**	3.002**
	(0.187)	(0.116)
var(constant)	0.243	0.139
	(0.051)	(0.029)
var(residual)	0.280	0.171
	(0.018)	(0.011)
Observations	522	531

Note. Standard errors in parentheses
* $p < 0.05$, ** $p < 0.001$

6. Discussion

In the research aim and hypotheses part of this study several research questions and predictions were composed. In this next part, these predictions are compared to the results of the analyses. In addition, the limitations of this experiment, possibilities for further research, and practical recommendations for urban parks are discussed.

6.1 Effects on perceived safety (RQ1)

The hypothesis of the first research question was that permeability below the horizon line and lighting positively influence perceived safety. Permeability above the horizon line was argued to not have an effect on perceived safety. However, the results showed that this hypothesis was not confirmed. Contrary to the expectation, permeability above the horizon line did have a significant effect on perceived safety. The results indicate that as this permeability's level increased, perceived safety increased too. However, permeability below the horizon line only had a significant effect for the 85% permeability level, and this was only when the laboratory-online interactions were excluded. The 85% permeability level was the highest of the three levels of this variable, which could indicate that a certain threshold has to be reached in order for permeability below the horizon line to have a significant effect on perceived safety. The significant effect disappearing after adding the laboratory-online interactions, could indicate that the effect was only there in the online version of the survey, but not in the laboratory setting (the reference level).

These results go against the hypotheses that were made about the permeabilities. In fact, the effects seem to be flipped; in the final model on perceived safety permeability above the horizon line did have a positive influence on perceived safety, whereas permeability below the horizon line did not. This could indicate that even though it does not directly influence the view around one's walking path, permeability above the horizon line could still affect the perceived levels of prospect, concealment or entrapment. This might be through possible hiding places (concealment) in the trees or simply because participants also need prospect into the higher area of their view in order to feel safe. Some participants also made remarks that the difference in vegetation above the horizon line stood out more compared to the permeability below, because of the contrast between the trees and the background sky. The levels below the horizon line were harder to distinguish, because vegetation alterations happened partly in the dark. Another reason for the lack of any effects of permeability below the horizon line might be because the participants valued the presence of light in this area more when evaluating their perceived safety. This would diminish the possible effects of permeability below the horizon line. However, such an interaction cannot be measured with the Taguchi design used here and should be investigated in future research.

In accordance with what was expected, the higher light levels had a significant positive effect on perceived safety. This means that when the illumination levels increased, perceived safety increased too. This can be because higher light levels might result in increased levels of prospect, and decreased levels of concealment and entrapment, which according to Fisher and Nasar (1992), and Nasar and Jones (1997) increases perceived safety levels. Still, it cannot be confirmed whether the light truly influenced perceived safety indirectly through the levels of prospect, concealment and entrapment, or that it was a direct effect.

6.2 Effects on perceived restorativeness (RQ2)

In the hypothesis of the second research question it was argued that the effect of permeability above and below the horizon line on perceived restorativeness would be an inverted U-shape. Low permeability results in low perceived restorativeness, moderate permeability in high perceived restorativeness, and high permeability in low perceived restorativeness. This is similar to what Jiang, Chang and Sullivan (2014) had found.

This hypothesis was not supported. Instead of an inverted U-shape, permeability above the horizon line had a significant positive effect on perceived restorativeness as it increased. On the other hand, permeability below the horizon line only gave insignificant results. A reason could be that the difference between the three percentages was not big enough to observe an inverted U-shape. However, for permeability above the horizon line (5%, 30% and 60%) there was already quite some difference and adding more trees to the videos might have made the park look unrealistic. For permeability below the horizon line (60%, 70% and 80%), lowering the levels would have resulted in placing bushes almost everywhere besides the footpath, because the path took up a large part of the view. Jiang, Larsen, Deal and Sullivan (2015) also measured a version of permeability in their study on landscape preference. Here, the permeability ranged from 35% to 100%, but they made no distinction in above or below the horizon line. Three other studies only measured the permeability below the horizon line (Lis et al. 2021; Lis & Iwankowski, 2021a; Lis & Iwankowski, 2021b). In these three studies the permeability ranged from 12.8% to 100%. In all cases pictures were taken of real-life environments. The fact that these were images of real situation shows that the range of permeability values can be broad, without feeling unnatural. In order to get natural-feeling park environments with greater differences in permeability, it might be best to create some options and let them be evaluated by experts and park visitors, or take inspiration from existing natural scenes.

Another explanation for the variables not having an inverted U-shape effect might be that increased permeability above the horizon line gave the opportunity to watch the night sky instead of dark trees. When the permeability was 5%, it might have been hard to distinguish the trees and see depth. This was partly because the street lanterns were facing downwards and did not illuminate the trees. Meanwhile, a starry night might also comply with the requirements for involuntary attention. Intuitively, one could say that a night sky with stars elicits soft fascination and could therefore, according to ART, enhance restoration. This means that the restoration would not have been the result of the decreased vegetation (increased permeability), but of the increased visibility of the night sky. Some studies already found a positive relation between viewing the day sky and restoration (R. Kaplan, 2001; Masoudinejad & Hartig, 2020). However, only one essay could be found that also argued the importance of a clear night sky for restoration (Kaiser, n.d.). So, to confirm this argument, the effect of a night sky on perceived restorativeness should be further investigated.

Regarding the light levels, it was expected that more lighting yields higher levels of perceived restorativeness, because of the increased visibility of the natural characteristics important in SRT and ART. Although the analysis showed positive effects of light on perceived restorativeness, the light levels, 3 and 5 lux, were very similar in size (respectively $\beta = 0.297$ and $\beta = 0.274$). This means that perceived restorativeness did not increase as more light was added, but instead decreased a little bit at the third level (5 lux). This could indicate that no great amount of light is needed to increase perceived restorativeness and that there might be a limit to what increasing the illumination can do to improve the restorativeness. Since this study only employed three light conditions, the existence of a limit cannot be proved currently. In order to confirm that there is a limit and what this limit is exactly, further research has to be done where more lighting conditions are investigated.

6.3 Effects of perceived safety on perceived restorativeness (RQ3)

The hypothesis of the third research question was that perceived safety would positively influence perceived restorativeness. This was argued from both the SRT and ART. SRT states that threatening situations elicit negative affect and thus restoration will not be possible (Ulrich, 1983). ART is based on the claim that restoration is actually the restoration of directed attention and can take place when involuntary attention is used (Kaplan, 1995). The current study argues that low perceived safety demands directed attention, meaning that restoration cannot take place.

The results of the experiment confirmed the hypothesis. However, only in the multi-level model where solely the average perceived safety per video was added as predictor, perceived safety had a positive significant effect on perceived restorativeness. In the following models, where other predictors were added, the effect of perceived safety became negative and was not significant anymore. In addition, none of the other manipulated predictors gave significant results, which means that adding perceived safety to the multi-level models on perceived restorativeness ensured that permeability above the horizon line and light lost their significance.

The results raise a question of what it is that was measured exactly. It seems like (part of) the three main variables might in reality explain the effect of perceived safety on perceived restorativeness. So, is perceived safety relevant in predicting the perceived restorativeness or are the factors that predict perceived safety more important? The explained variances of the models are almost equal (all around 50%), so this does not give a clear answer. When taking a look at the main effects on both perceived safety and perceived restorativeness, it can be seen that the variables with significant effects are permeability above the horizon line and light. Of these variables, all estimates are positive and thus they all have the same direction of effect on perceived safety and perceived restorativeness. Therefore, it might be that the main variables and the perceived safety variable are high in multicollinearity and are actually measuring the same concept. Due to including the main variables separately from the perceived safety variable in the analysis, the variation in physical characteristics was mostly controlled for and the effect of perceived safety disappeared. All this would indicate that predicting the perceived restorativeness with the perceived safety variable is redundant when the main variables are also included.

The finding that permeability above the horizon line and light had the same direction of effect on both perceived safety and perceived restorativeness can be useful for designing urban parks. It shows that landscape designers can improve both the safety and restoration levels in parks by increasing the amount of permeability and lighting. Future research should investigate whether there is a limit to this effect and what levels of permeability and illumination would be best.

6.4 The influence of the survey setting

A boxplot and ANOVA-analysis showed that there was a significant difference in perceived safety between the laboratory and online setting. This was not the case for perceived restorativeness. Participants who made the survey online reported significantly higher levels of perceived safety than those who filled it out in the laboratory. Thus, the setting in which the participants completed the survey was relevant to the results of the experiment. This means that the setting should be considered carefully and simply asking participants to rate videos on their own devices might give results that are attributable to other factors than the survey videos.

Because of the significant difference in perceived safety, it was decided that the laboratory-online variable should be included in the multi-level models. The interactions between laboratory-online and permeability above the horizon line, permeability below the horizon line and light were added too.

Again, the models on perceived safety showed that making the survey online instead of in the laboratory had a positive effect on the results. An explanation for this effect could be that participants feel more safe in an environment of their choosing. Some participants might never have been in the laboratory before and could have felt that the procedure was a hassle. Meanwhile, the online survey gave them the opportunity to pick a comfortable location and take their time to complete it. In addition, it is likely that the room lighting in the laboratory setting (E_h = 78-100 lux, E_v = 70-85 lux) was lower than wherever they chose to make it online. The recommended illumination levels for workplaces are much higher than they were in the cubicles (NEN, 2021), so this might also have influenced the perceived safety ratings.

There were also some significant interaction effects on perceived safety. In the online setting, participants reported higher perceived safety for 70% permeability below the horizon line than in the laboratory. The same reason as mentioned before could apply to this effect; the familiarity of the self-chosen online setting might positively influence how the permeability is perceived.

Another significant interaction effect was between laboratory-online and 5 lux light. This meant that the effect of the 5 lux level on perceived safety was smaller in the online setting compared to in the laboratory. A possible explanation for the effect of setting is that the light conditions of the laboratory influenced the perceived safety ratings. Because the light conditions were low, the lack of lighting in the videos might have become more prevalent, lowering the perceived safety scores. However, this explanation makes it odd that there is no significant interaction with the 3 lux light level.

Regarding the multi-level models on perceived restorativeness it turned out that, as the ANOVA-analysis already showed, the laboratory-online variable had no significant effects. Nonetheless, the interactions with light did produce significant effects. The effects on perceived restorativeness of both 3 and 5 lux lighting were smaller online than in the laboratory. These interaction effects were in fact so large that they almost completely diminished the significant estimates of the main effects of light. This means that the light levels had no effect on perceived restorativeness when the survey was made online. A possible reason could be the difference in computer screens between participants. Due to these differences the lighting of the videos might have looked too different between participants for an effect to occur.

The discussed interaction effects of laboratory-online show us that online studies, where a visual evaluation is necessary, should be performed with great caution. In addition, studies where the dependent variable is something that can be influenced by the surrounding environment should also be approached carefully. Ideally, online studies should only be done when it is possible for every participant to use screens with similar visual qualities or when dependent variables that do not rely on one's mental state or visual perception are measured. Otherwise, it might be sensible to try to take the varying environments into account, for instance with the use of sensors in computers or mobile apps, or through a list of questions at the start of the survey.

6.5 The influence of demographical variables

Lastly, it was investigated whether any demographical variables or their interactions might be relevant in predicting perceived safety and perceived restorativeness. After running a simple multi-level model with these variables, it turned out that the only demographical variable that was suitable of further investigation was gender. The age, kind of living place (e.g. in a city, village, etc.), education and average number of visits to a park of the participants did not influence the perceived safety or perceived restorativeness scores. Regarding the effect of age, it makes sense that nothing substantial was found. Most participants were students in their 20s ($M_{age} = 24.8$, $SD_{age}= 9.0$, age range = 18-59), which resulted in a participant sample that barely had any variability. For education, it might have be sensible to change the question a little. Right now, it was asked what their highest finished education level was, to which a lot of people answered high school. However, a lot of these people were actually attending university at that time. By asking what education they finished instead of what they were currently doing, all different levels of education after high school were reduced to one group, which could have led to a group that was too diverse.

To further investigate gender, two multi-level models on perceived safety and perceived restorativeness were created. In these models the main variables, laboratory-online, gender, and interactions with gender were included as predictors. It could be seen that males reported higher perceived safety than females. However, this effect was smaller for the 5 lux lighting level, indicating that females are more sensitive to increases in illumination than males are. This is a finding that is supported by many previous studies on the relation between gender differences, light and perceived safety (e.g. Boomsma & Steg, 2014; Boyce et al., 2000).

No significant effect of gender on perceived restorativeness was found. So, this indicates that one's gender does not influence perceived restorativeness. However, there was a significant effect of the interaction between gender and laboratory-online; compared to females, males reported lower perceived restorativeness when they made the survey online. In fact, this estimate was large enough to revert the direction of the main effect of laboratory-online, though this main effect was insignificant ($\beta = 0.207 - 0.624 = -0.417$). This gives the indication that male participants report higher perceived restorativeness in the laboratory setting and female participants do so in the online setting. The reason for this is unclear and no other studies could be found were the same effect was present. Thus, further investigation is needed to confirm this interaction between gender and setting.

6.6 Limitations of the study and further research

Naturally, there were some limitations to this study. First of all, regarding the materials of the experiment, several participants remarked that they could not properly make distinctions between the videos. Maybe they subconsciously still noticed the differences, but for future research it might be better to have larger differences within the variables permeability above the horizon line, permeability below the horizon line and light. Changing the permeabilities was already discussed in section 6.2, but altering the illumination values should also be done with caution. The current values were chosen based on Fotios and Castleton's (2016) research and they state that increasing the illuminance level above 5 lux only has negligible benefit on perceived safety. Since the highest level of illumination in this experiment was already 5 lux, this would mean that there is not much room to change the illumination levels. Of course, it could still have a significant influence on perceived restorativeness, so further investigation in this research area is necessary to be certain of the effects of light on restorativeness in the dark. In addition, there was another issue about the illumination levels in this experiment; Because the videos were made using the TwinMotion program, there was no way to be exactly sure that the illuminance levels were truly 1, 3 and 5 lux. The program only had the possibility to set the amount of lumen of the light sources, and using this and the height of the light source, the illumination could be calculated. For future research it might be beneficial to use a program that is specifically intended for lighting design.

Another issue about the materials of the experiment was that the values of the permeability variables were chosen without much scientific substantiation. There were hardly any studies to be found on what percentages should be chosen, so the values were selected by hand, looking at what seemed to provide a realistic view. Nonetheless, this way of measuring the permeability still has the advantage of being a good objective measurement technique. A lot of studies in this research field count the amount of vegetation and place it evenly distributed across a park. However, the evenly placed vegetation could make the park lose its natural feeling, and this technique does not take the location of the viewer relative to the surroundings into account. Meanwhile, measuring the unobstructed view in percentages is a good way to also consider the distance of the observer to the vegetation. As previously mentioned, bigger differences between the percentages, while minding the natural look of the park, could be a next step in researching the influence of permeability on perceived safety and perceived restorativeness at nighttime. The current study design and its limitations might help determining better permeability values in the future.

There might be a better way to measure perceived restorativeness than was conducted in this experiment. When looking at SRT, it could be argued that stress reduction in natural environments solely takes place when the initial affective state is negative (Ulrich, 1983). Assuming that there is a limit to the amount of restoration, people that do not feel stress and are already in a positive affective state are not likely to get restoration out of a visit to the park. Arguing this point from ART (Kaplan, 1995); if there is no initial resource deficiency, then there is no need for restoration. Thus, to accurately measure the perceived restoration of participants, it might be necessary to measure or manipulate this initial state. It could be wise to start the survey with a demanding task to increase stress levels. This would make sure that for all participants there is something to be restored and would allow for the measurement of perceived restoration while the videos are being watched.

Another limitation of this study is the extent to which the results can be translated to real parks. This translation should be done with caution, because although it has been found that a virtual environment is reviewed as a realistic representation of the real world (Bishop & Rohrman, 2003), people do not evaluate real environments exactly the same as their virtual counterparts (De Kort et al., 2003). To be able to say anything substantial of the validity of the results of the current study, future research should investigate whether there are differences between evaluations of virtual parks and parks in the real world.

Furthermore, the virtual park was located in Eindhoven and the time and date was set to 11:00 PM in August with a little cloud cover. Naturally, vegetation will look different in other locations and seasons. It cannot be said if the same results as this study will come from a study with bare trees in winter for example. The same holds true for other weather conditions. Right now, depending on the permeability above the horizon line, a variety of stars could be seen. However, with more cloud cover the view would have become darker, which could have resulted in different effects on perceived safety and perceived restorativeness. Thus, one should be careful in trying to translate the found effects to urban parks in other locations, seasons, and weather conditions. Different weather conditions and seasonal changes could be included as independent variables in further research.

Lastly, in the current experiment it was chosen to limit the independent variables to permeability above and below the horizon line and light, but there are other park attributes that might influence perceived safety and perceived restorativeness. Examples are the presence of other people, litter, benches, flowers or bodies of water. The number of included attributes should be chosen with care though, because adding too many attributes, and therefore needing more video alternatives, results in a longer survey and could lead to participant fatigue.

7. Conclusion

This study aimed to find to what extent permeability above and below the horizon line and light influence the perceived safety and perceived restorativeness in urban parks at nighttime. Additionally, it aimed to find to what extent perceived safety influences perceived restorativeness. The results can help to better understand the relations between permeability, lighting, perceived safety, and perceived restorativeness in urban parks.

Despite its limitations, this study provides interesting findings. First of all, permeability above the horizon line and light had a positive effect on both perceived safety and perceived restorativeness. The fact that the direction of these effects is the same could be very convenient for urban park design. It shows that increasing the permeability and lighting in urban parks will both lead to increased perceived safety and perceived restorativeness, and yields no contradictory effects.

This results of this study did not lead to a clear understanding of the relation between perceived safety and perceived restorativeness. It is uncertain whether perceived safety directly influences perceived restorativeness or that the influence can actually be attributed to the permeability and light variables. It could be argued that the main predictors are a partial substitute for perceived safety when predicting perceived restorativeness.

Another finding is that online surveys cannot simply be compared to surveys that are made in a controlled setting. This is especially true for studies where some visual evaluation is needed, or where someone's mental state is measured. Here, the found effects could be due to differences in computer screens and surroundings instead of the factors in the videos.

Although more research is needed on the exact levels, it can be said that the main result of this study is that either permeability or lighting can be manipulated in a similar way to increase both perceived safety and perceived restorativeness. The next step is to confirm the findings in further experiments, after which the knowledge can eventually be used to make urban parks an even better place for one's psychological wellbeing.

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Appendix

Appendix A: Images of all video alternatives

Alternative 1: 60% permeability above horizon line, 85% permeability below horizon line, 1 lux light

Alternative 2: 60% permeability above horizon line, 70% permeability below horizon line, 3 lux light

Alternative 3: 60% permeability above horizon line, 60% permeability below horizon line, 5 lux light

Alternative 4: 30% permeability above horizon line, 85% permeability below horizon line, 3 lux light

Alternative 5: 30% permeability above horizon line, 70% permeability below horizon line, 5 lux light

Alternative 6: 30% permeability above horizon line, 60% permeability below horizon line, 1 lux light

Alternative 7: 5% permeability above horizon line, 85% permeability below horizon line, 5 lux light

Alternative 8: 5% permeability above horizon line, 70% permeability below horizon line, 1 lux light

Alternative 9: 5% permeability above horizon line, 60% permeability below horizon line, 3 lux light

Appendix B: Complete overview of the survey questions

Perceived safety questions:

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I would not mind to walk along this place unaccompanied	○	○	○	○	○
I would take a long detour to avoid this place	○	○	○	○	○
I would quickly get away from this place	○	○	○	○	○
I would have an unpleasant feeling in this place	○	○	○	○	○
I would feel uneasy in this place	○	○	○	○	○
I would feel safe in this place	○	○	○	○	○
I would feel anxious in this place	○	○	○	○	○

Perceived restorativeness questions:

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Being here is an escape from experience	○	○	○	○	○
Spending time here gives me a break from my day-to-day routine	○	○	○	○	○
This is a place to get away from it all	○	○	○	○	○
This place has fascinating qualities	○	○	○	○	○
My attention is drawn to many interesting things	○	○	○	○	○
I want to get to know this place better	○	○	○	○	○
This is a confusing place	○	○	○	○	○
There is a great deal of distraction here	○	○	○	○	○
It is chaotic here	○	○	○	○	○

Demographical questions:

This is the last part of the survey. Please answer these demographical questions.

What is your gender? *

Please choose only one of the following:

- ◯ Female
- ◯ Male
- ◯ Gender-neutral
- ◯ Prefer not to say
- ◯ Other [ ]

What is your age? *

Please write your answer here:

[ ]

What is the highest level of education you have completed? *

Please choose only one of the following:

- ◯ High school
- ◯ MBO / Secondary vocational education
- ◯ HBO / University of applied sciences
- ◯ WO Bachelor
- ◯ WO Master
- ◯ PhD
- ◯ Prefer not to say
- ◯ Other [ ]

Where do you currently live? *

Please choose only one of the following:

- ◯ In the countryside
- ◯ In a village
- ◯ In a town
- ◯ In a city
- ◯ Prefer not to say
- ◯ Other [ ]

How often do you visit a park (on average)? *

Please choose only one of the following:

- ◯ Never
- ◯ Once a year
- ◯ Few times a year
- ◯ Once a month
- ◯ Once every two weeks
- ◯ Once every week
- ◯ Multiple times a week
- ◯ Prefer not to say
- ◯ Other ________

Do you have any comments about this survey? Please leave them here:

Please write your answer here:

This question is optional.