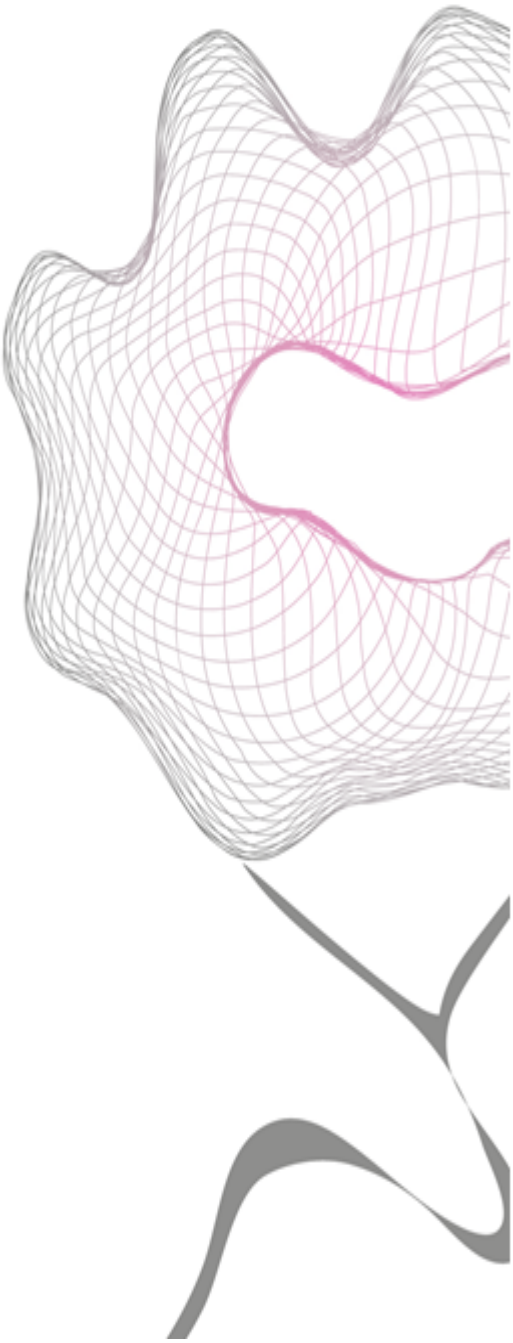

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# Master Thesis –

## *The Role of Urban Green Spaces in Perceptions of Safety and Situation Construal*

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**Abstract**

Increasing safety perceptions in public spaces has become a worldwide concern, as safety is a primary component of quality of life. Research demonstrates a relationship between urban green space(s) (UGS) and perceptions of safety. However, a complex duality of UGS – restorative but also threatening – and little evidence about causal effects show the need for further investigation. Therefore, this study aimed at adding to existing literature investigating the relationship between UGS and safety perceptions through the employment of a between-groups experimental design. More specifically it aimed to determine to what extent the presence and maintenance of UGS affect safety perceptions and interpretations of an ambiguous situation. For this purpose, behavioral and perceptual responses of three different groups ($n$ = 26) were compared after exposure to a virtual reality (VR) environment that differed in the presence and maintenance of UGS. Participants ($N$ = 78) were either exposed to a neighborhood featuring well-maintained, uncared, or no UGS. Findings predominantly suggest that it does not make a difference whether UGS are well-maintained, uncared or present at all, in how safe people feel and how they frame social situations. The counter-intuitive result might have to do with the study's design. Even though the study takes into account that the influence of UGS on perceived safety will vary depending on a number of spatial attributes, more attention should be given to the situated context. The VR neighborhood was of relatively poor quality. Hence, a situational setting, which features neighborhood characteristics indicative of social and physical disorder, calls for particular attention to the level of maintenance and visibility of UGS to overshadow negative effects of other environmental cues. The study findings could also point towards the interaction of several social or physical features of the built environment. Well-maintained UGS alone may not considerably influence cognitive responses comprising safety perceptions and situation construal. Possible directions for future research point to adding embellishment that further increases the visibility and maintenance of UGS or combining UGS with additional urban design measures that enhance positive environmental perceptions. Further investigation into the effect of UGS on safety perceptions is vital as it can guide urban planning efforts in providing recommendations for more effective crime prevention strategies. Moreover, UGS knowingly benefit well-being and mitigate the 'urban heat island' effect. Gaining deeper insights from future research may help urban planners to include considerations in interventions improving the mental-restoration and thermal comfort experienced in a place.

*Keywords:* urban green spaces (UGS), perceptions of safety, fear of crime, VR

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**The Role of Urban Green Spaces in Perceptions of Safety and Situation Construal**

Issues of public safety, such as crime and the fear of crime, pose a serious threat to individuals' and communities' well-being and are therefore among the most important concerns of the present. For instance, fear of crime "has been found to limit activities and territory, heighten stress, make people feel like prisoners in their homes and neighborhoods, disrupt neighborhood cohesion and, by doing so, may actually increase crime" (Nasar & Fisher, 1993, p. 187). In contrast, perceptions of safety contribute to greater cardiometabolic health due to increased outdoor activity (Baldock et al., 2018), greater neighborhood and life satisfaction (Mouratidis, 2019), and were found to predict well-being and mental health (Green et al., 2002).

In order to increase safety perceptions in public space and to deter criminal activity, many crime prevention strategies rely on heightened surveillance and implementing stricter measures against violations of the law (Wolfe & Mennis, 2012). However, according to Nasar and Fisher (1993), micro-level physical (e.g. places of concealment) and social features (e.g. approaching strangers) of the built environment also play an important role in influencing crime and fear. They argue that more attention should be given to physical, site-specific features, because these can be controlled for. Some crime prevention strategies, such as those based on Crime Prevention Through Environmental Design (CPTED), already focus on altering features of the built environment specifically with crime suppression in mind (Bogar & Beyer, 2015).

One particular aspect of the built environment that might influence perceptions of safety pertains to the amount of vegetation or green space. However, the role of urban green space(s) (UGS) appears ambiguous. Some believe that UGS can be perceived as dangerous because they promote crime and the fear of crime by providing concealment for offenders and hindering escape for victims (Fisher & Nasar, 1992; Nasar & Fisher, 1993, Nasar & Jones, 1997). Especially, dense and low-lying vegetation, such as shrubs and trees, were found to increase perceptions of fear (Talbot & Kaplan, 1984; Nasar & Fisher, 1993; Donovan & Prestemon, 2012), and thus they are often advised to be removed (Lis et al., 2019).

Yet, other studies suggest that UGS, especially if visibility-preserving, are linked to lower levels of crimes, including violent crimes, property crimes (Kuo & Sullivan, 2001a), assault, robbery, and burglary (Wolfe & Mennis, 2012). Furthermore, interaction with unthreatening UGS enhanced the perception of safety (Garvin et al., 2013). UGS stimulate outdoor activity and thereby increase natural surveillance through more 'eyes on the street' (Kuo & Sullivan, 2001a) as well as relaxation, positive thoughts, and elevated mood levels

(Ulrich, 1986). According to the attention restoration theory from Kaplan and Kaplan (1989), viewing or interacting with vegetation has mental restorative potential due to nature's ability to engage our attention in an effortless manner leaving enough mental capacity for contemplation and reflection on other lingering thoughts. These positive associations of UGS (e.g. encouraging psychological well-being and outdoor activity), if acknowledged by the perceiver, could steer a person towards framing perceptions and interactions within environments that feature UGS in more positive terms. This assumption is based on research stating that people's perceptions are shaped in ways that conform to the meanings they associate with objects in their environments (Van Rompay et al., 2015). Hence, the removal of UGS should be dealt with caution because of both their health-promoting and socially beneficial functions (Lis et al., 2019).

The complex duality of UGS – restorative but also threatening – shows the need for further research into the relationship between UGS, crime, and the fear of crime. In addition, most studies to date have only provided evidence of a correlation and have had little to say about causation (Kondo, Han, Donovan, & MacDonald, 2017), which is why there is a need to determine the direction of the relationship. For instance, the research findings mentioned earlier by Kuo and Sullivan (2001a) and Wolfe and Mennis (2012) are based on self-reports and the analysis of crime data over a prolonged time period. Hence, it seems appropriate to attempt an intervention study employing a true experimental design to further test some of the assumptions about the effects of vegetation on crime. However, this research will focus on the fear of crime rather than actual crime. More specifically, it attempts to determine whether the presence of UGS predicts how safe people feel. It will complement existing research investigating the relationship between UGS and fear of crime by allowing inferences about causality through the employment of an experimental design. This, in turn, will have implications for crime prevention by providing recommendations for more effective urban planning efforts (for instance how UGS can be designed to maintain perceived safety without losing their restorative benefits). Furthermore, urban planning that is both sustainable and crime preventative will also prove valuable to urban environments that are not only prone to high crime-rates but also deal with temperature increases due to vegetation decline, often known as the 'urban heat island' effect (Soltani & Sharifi, 2019). Hence, the following research question will be examined: *To what extent does the presence and maintenance of UGS affect perceptions of safety and how people interpret an ambiguous situation?*

## Theoretical Framework

There are several criminology theories that explain how site-specific features in the built environment might simultaneously heighten fear and facilitate criminal activity. At the same time, these theories provide insights into the conditions under which the built environment might contribute to greater safety perceptions and crime prevention. The following paragraphs first define the concept of fear of crime and how this study seeks to measure it. Second, based on criminology theories, it is discussed in what ways UGS can influence criminal activity and how safe people feel in their environment.

### *Conceptualizing Fear of Crime*

Fear of crime is a serious source of stress that threatens people's well-being and quality of life (Nasar & Jones, 1997). In the literature, it is often viewed as "a negative emotional reaction demonstrated as the fear of criminality and victimization" (Pánek et al., 2019, p. 2). It is part of the dimension of safety that belongs to the subjective safety, experienced by the individual (Lis et al., 2019). However, there seems to be less consistency in how this concept is being measured. Some scholars view the fear of crime as being synonymous to perceptions of safety and argue that measures of these constructs can be used interchangeably (Baba & Austin, 1989; Okunola & Amole, 2012). Others, however, argue that perceived safety and risk measures, which are often used to represent fear of crime, fail to capture the emotional aspect associated with the fear of crime (Hinkle, 2014).

The lack of consistency in the measurement of this concept could partially be explained by a distinction between viewing the fear of crime as a personality trait (dispositional fear of crime) or as "a momentary affective state that varies within a person according to the situation at hand" (situational fear of crime) (Gabriel & Greve, 2003, p. 601). The choice of measurement then possibly depends on the focus of interest. Emotional fear measures can be more suitable when fear disposition is to be measured, while perceived safety or risk measures may be sufficient in capturing situational fear of crime. The choice of measurement may also be influenced by an assessment of people's willingness to answer honestly. Scholars' may resort to measures that ask about perceived safety or risk rather than the fear of crime, as people have been found to be more willing to report perceptions related to feelings of insecurity or risk of victimization than their fear of crime (Hinkle, 2014).

The current study focuses on situational fear of crime. However, dispositional fear of crime was investigated as a moderator and covariate as it was found to influence the likelihood of experiencing fear in a given situation (Gabriel & Greve, 2003). For a full understanding of situational fear of crime all of its three components, namely an affective,

cognitive, and expressive (behavioral) facet, would have to be considered (Gabriel & Greve, 2003). This study is mainly interested in whether features in the environment can influence the cognitive perceptions in the present moment. Hence, a measure asking about perceptions of safety/fear/risk was deemed to be operational, because it has a strong reference to perceptions in the moment. Perceptions are easier to grasp for people and as stated before were found to be more commonly disclosed than emotions, like being afraid of crime (Hinkle, 2014). To avoid confusion whenever speaking of this measuring instrument, it will henceforth be referred to as 'perceived safety'. Apart from a cognitive/perceptual facet this study also included a behavioral outcome measure that captured participant's decision time for choosing a path and their subsequent path selection.

The perception of fear and safety is not believed to follow a uniform distribution among time, population and space. For example, concerns about fear and safety are often more pronounced after dark (Nasar & Fisher, 1993; Kimpton et al., 2016), and among women as compared to men (e.g. Nasar & Fisher, 1993; Koskela & Pain, 2000; Jiang et al., 2017; Ferraro, 1995). According to the victimization model, those who experienced criminal victimization or who perceive to be vulnerable to crime (usually women and the elderly) show greater levels of perceived fear (Karakus et al., 2010). Research supports that direct and indirect victimization has a significant impact on perceptions of risk and safety in the neighborhood (Taub et al., 1981; Greenberg & Rohe, 1984). Furthermore, fear of crime seems to concentrate in certain areas, called hot spots (Nasar & Fisher, 1993), which are classified as unsafe through direct or indirect (e.g. media reports) experience (Nasar & Fisher, 1993). According to the routine activity theory (Cohen & Felson, 1979), areas become hot spots of fear and crime given the presence of a motivated offender, a suitable target, and a lack of guardianship. Incivilities become more likely and therefore increase the likelihood of picturing this area as unsafe (Nasar & Fisher, 1993).

***The Role of Prospect and Refuge in Perceptions of Safety***

Nasar and Fisher (1993) stress the importance of site-specific features of the physical environment in influencing safety perceptions. Furthermore, they mention that people scan their immediate environment for cues to danger when feelings of fear arise. According to the prospect-refuge theory, people prefer environments that offer both prospect (an open view) and refuge from a potential threat, because it aids survival (Fisher & Nasar, 1992). However, the same holds for offenders who prefer places that afford seeing (prospect) without being seen (concealment) (Fisher & Nasar, 1992). This provides important implications for safety perceptions. Based on this theory, Fisher and Nasar (1992) argue that the fear of crime would

be the greatest in places that provide limited prospect (e.g. due to dense shrubs) but give the offender opportunities to hide. Aside from prospect and refuge, they believe that the degree to which a place provides an opportunity to escape from a threat influences safety perceptions and fear of crime. A study by Lis et al. (2019) supports the notion that prospect, refuge, and escape are among the primary predictors of danger and that specific types of vegetation, especially shrubs (in comparison to trees), decrease safety perceptions. The authors argue that even though trees can provide a hiding place, they hinder escape and prospect to a lesser extent than shrubs. Yet, the extent to which shrubs and trees influence perceived danger is argued to vary depending on other spatial features as well, such as their composition, density, or their quantity (Lis et al., 2019).

***The Effect of Green Space on Routine Activities***

In contrast to the prospect-refuge theory, the aforementioned routine activity theory argues that for a crime to happen there must be a motivated offender, a suitable target, and a lack of guardianship. Vegetation mostly plays a role in the third component of this theory. Rather than only altering the physical appearance of urban space, vegetation might actually promote routine activities in a neighborhood. In other words, public spaces which entice individuals to engage in outdoor activities and community bonding, often known as social cohesion, lead to more 'eyes on the street' and therefore greater natural surveillance (Bogar & Beyer, 2015; Lee et al., 2016; Pánek et al., 2019). Consequently, criminal activity is impeded, as offenders tend to avoid these areas (Kuo & Sullivan, 2001a).

Research supports the view that vegetation increases the use of public space, and thus surveillance. For example, a study by Kuo and Sullivan (2001a) found that vegetation was linked to lower violent and property crimes, which they ascribed to the greater use of public space with greenery, next to the mentally restorative effects of vegetation. Donovan and Prestemon's (2012) study of crime in Portland, Oregon, further supports the notion of routine activity theory that vegetation increases the desirability of public space and therefore the potential for 'eyes on the street'. In particular, large trees that provide little opportunity for concealment and convey maintenance of the public space were found to be better crime suppressants compared to small, view-obstructing trees. Furthermore, Garvin et al. (2013) attributed the positive effects of vacant lot greening on perceptions of safety to the potential of well-maintained, small-scale UGS for encouraging outdoor activity in ways that enhance a communities' social cohesion, which alleviates stress and mental fatigue. Areas that are perceived to have high social cohesion, meaning that residents are perceived to have good

interpersonal connections, are thought to be the ones where people feel the safest and most comfortable to walk (Jennings & Bamkole, 2019).

### *Green Space and Perceived Disorder*

Another criminology theory, the broken windows theory, mainly directs interventions toward focusing on the physical appearance of a place rather than improving social dynamics. This theory suggests that certain characteristics of the built environment signal physical disorder and therefore increase social incivilities and fear of crime (Jiang et al., 2017). For example, abandoned buildings and littering signal that a place is not cared for and lacks social control, suggesting to criminals that they are better off committing vandalism and crime (Jiang et al., 2017). When vegetation is poorly maintained it can signify disorder and a lack of social control as well (Wolfe & Mennis, 2012). Similarly, Lis et al. (2019) suggest that any signs of deterioration that could instill a sense of danger, such as wild and neglected vegetation, should be avoided. For this reason, intervention strategies rooted in broken windows theory, such as those that follow CPTED principles, involve environmental clean-up to promote an image of civility and maintenance (Lee et al., 2016). In a study by Garvin et al. (2013) the restoration of vacant lots, through e.g. planting grass and trees, increased perceptions of safety. Similarly, it was found that interventions involving the cleaning and greening of vacant land significantly reduced crime, the perceptions of crime, vandalism, and the sense of insecurity when going outside (Branas et al., 2018).

### *The Effect of Green Space on Mental Health*

Other literature, guided by the stress recovery theory from Ulrich (e.g. Ulrich et al., 1991) and the attention restoration theory from Kaplan and Kaplan (1989) suggests that the mere presence of greenery in an environment has additional psychological benefits for individuals. According to the stress recovery theory, interaction with unthreatening UGS triggers positive affective responses, which influence adaptive behaviors and psychological functioning such as relaxation and having fewer negative thoughts and moods (Van den Bogerd et al., 2018). Indeed, research has shown that viewing greenery had therapeutic influences on hospital patients and helped them to recover faster by reducing stress or anxiety (Ulrich, 1984). As mentioned earlier, attention restoration theory argues that green environments can help people to alleviate mental fatigue because nature has the ability to "engage attention in an effortless and involuntary manner" (Bogerd et al., 2018, p. 3). Literature associates mental fatigue with being a psychological precursor to crime (Wolfe & Mennis, 2012; Chan, 2015). Hence, these mentally restorative effects of UGS are especially

interesting to take into account if the focus were to prevent people from engaging in anti-social behaviors.

In the present study, which focuses on safety perceptions of the innocent passerby, the mentally restorative effects of UGS could also play a role. Research has shown that people's perceptions and behaviors are shaped in ways that conform to the meanings they associate with objects in their environment (Van Rompay et al., 2015). Hence, when people associate UGS with something positive, such as having health-promoting functions, adding UGS to an environment might also influence people to perceive this environment and to frame any interaction within it in more positive terms. As stated before, environments that provide UGS, especially if well-maintained, are preferred. These environments afford opportunities for outdoor activities and social interactions with others, which promotes perceptions of social cohesion. In this way, UGS are not only health-promoting for residents living in such a neighborhood, but they are also the pathway through which any passerby could come to perceive a neighborhood as safe and non-threatening.

**The Current Study**

This research aims to determine whether the presence of well-maintained UGS positively impacts cognitive experiences comprising perceptions of safety. Moreover, it seeks to find out whether such an environmental setting induces people to frame an ambiguous situation in more positive terms. The following research question was investigated: *To what extent does the presence and maintenance of UGS affect perceptions of safety and how people interpret an ambiguous situation?* Drawing on existing research and criminology theory, the following hypotheses were formulated:

**H1:** The well-maintained UGS group scores higher on perceived safety at night compared to the two other groups, and this effect is moderated by dispositional fear of crime; when dispositional fear of crime is low, this effect will be stronger than when dispositional fear of crime is high (see Figure 1, p. 8).

**H2:** Well-maintained UGS cause more positive interpretations of ambiguous situations, and this can be explained by perceived safety (perceived safety acts as a mediator for the relationship between well-maintained UGS and interpretation of ambiguous situation; see Figure 2, p. 9).

**H3:** The presence of UGS (whether uncared or well-maintained) causes more positive interpretations of ambiguous situations compared to when there are no UGS, and this effect becomes stronger as perceived benefits of nature increases (see Figure 3, p. 9).

The hypotheses were tested by comparing three groups in a virtual reality (VR) environment. Participants were either exposed to a neighborhood that featured well-maintained UGS, uncared UGS, or no UGS. First, to get participants acquainted with the VR environment they explored it by daylight. Subsequently, to further manipulate safety perceptions, they experienced the environment by night and were exposed to an ambiguous situation that involved three young men hanging around in an urban park area. The intention was to keep the situation open to interpretation and thereby reduce the possibility of biasing the participants. During this night exposure participants made a choice of either turning left (and moving closer to the ambiguous situation) or right (moving away from it). After each VR exposure participants received a number of questions intended to measure their safety perception and social cohesion in the neighborhood. Furthermore, after the night exposure, they were asked to interpret the ambiguous situation and to answer a set of questions intended to measure demographics and several potential confounding variables.

**Figure 1**

*Conceptual Model of the Expected Moderation Effect of Dispositional Fear of Crime on the Relationship Between Well-Maintained UGS and Perceived Safety (H1)*

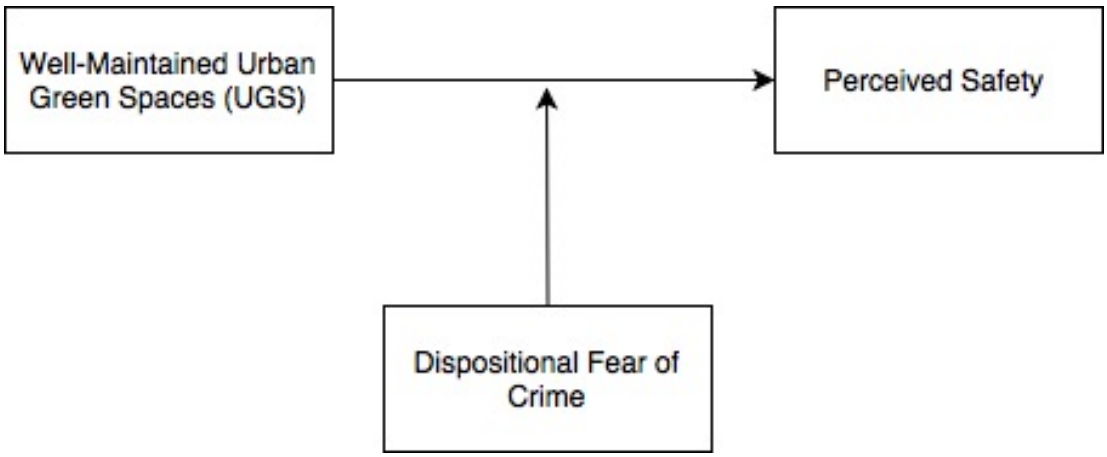


**Figure 2**

*Conceptual Model of the Expected Mediation Effect of Perceived Safety on the Relationship Between the Degree of Maintenance of UGS and Participant's Interpretation of the Ambiguous Situation (H2)*

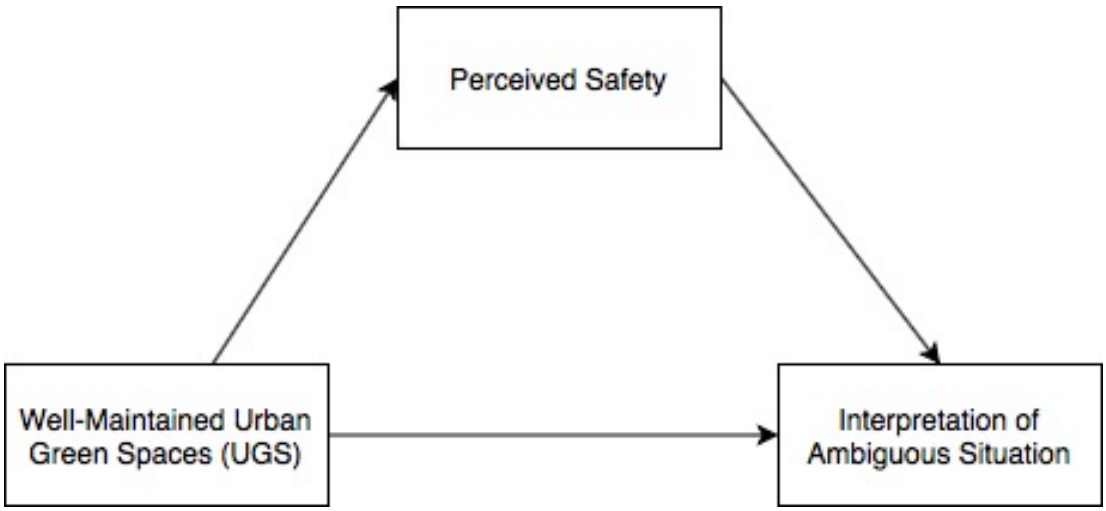
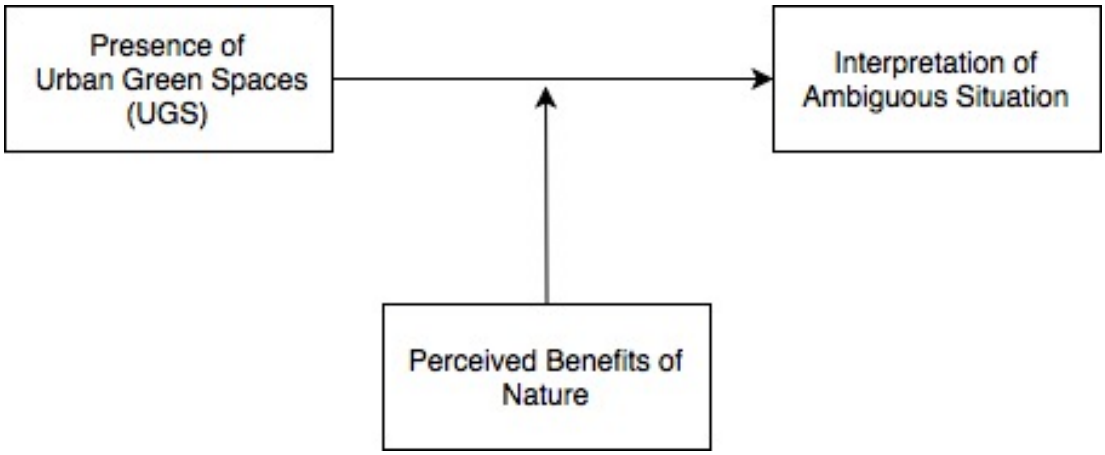



**Figure 3**

*Conceptual Model of the Expected Moderation Effect of Perceived Benefits of Nature on the Relationship Between the Presence of UGS and Positive Interpretation of Ambiguous Situation (H3)*




## Methods

### Ethics

The BMS Ethics Committee of the University of Twente approved this research. Upon arrival, participants received a detailed informed consent including the purpose of the study, procedures, any potential risks and benefits, confidentiality, compensation for taking part in the study, the right to withdraw at any time and the statement of consent.

### Participants and Design

In this research, a between-groups experimental design was employed. Participants were randomly assigned to three groups, which differed in the presence and the degree of

maintenance of UGS enclosed in a VR environment. In other words, the independent variable UGS consisted of three levels, present and high maintenance versus present and low maintenance versus absent (control). In all groups the participants first experienced the VR environment and subsequently filled out a questionnaire. Data was collected after the first and the second part of the VR experiment, with perceived safety (representing situational fear of crime) and interpretation of the ambiguous situation as the dependent variables.

Ultimately, the study comprised a convenience sample including a total of ($N$ = 78) participants aged between 18 to 38 years ($M$ = 22.27, $SD$ = 3.57). Each participant was randomly allocated to one of three groups with ($n$ = 26) in each group. The sample was recruited through the student participation panel for online studies, called SONA, of the University of Twente in Enschede and via word-of-mouth marketing. The inclusion criterion was a minimum age of 18 years. Descriptive statistics of the final sample are given in Table 1. The study was available online from September 1 until October 6, 2020.

**Table 1**
*Demographic Characteristics of the Respondents (N = 78)*

| Variable | Frequency | % |
|---|---|---|
| Gender | | |
| Female | 47 | 60.3 |
| Male | 31 | 39.7 |
| Nationality | | |
| German | 43 | 55.1 |
| Dutch | 12 | 15.4 |
| Other | 23 | 29.5 |
| Occupation | | |
| Employed full-time | 1 | 1.3 |
| Employed part-time | 2 | 2.6 |
| Student | 75 | 96.2 |
| Previous Victimization | | |
| Yes | 41 | 52.6 |
| No | 37 | 47.4 |

## Apparatus and Materials

In this study, three VR environments were designed using the 3D game development platform Unity® 2019.3.10 (Unity Technologies, 2020). All environments display the same neighborhood with an identical type of housing and street layout. However, they differ in the presence and maintenance of UGS. The control group does not feature any UGS, while the other two environments either feature well-maintained, small-scale UGS or uncared UGS. Furthermore, for every group, the VR experience was split into two parts. In the first part,

participants experienced the environment in daylight while the second part offered a night experience. Further differences between the day and night exposure are delineated in greater detail in the 'procedure' section below. Other VR equipment included an Oculus Rift S head-mounted display controlling head movements, with a field-of-view of 115°, and a resolution of 2560 x 1440 pixels per eye displayed at 80 Hz. Besides, a locomotion device, the Cyberith Virtualizer Research & Development Kit, was used to enable full movement in virtual environments and to contribute to a more immersive experience. For the execution of the experiment, it was required to have a PC running the Unity program, a storage device to safely store the data, and ear-enclosing headphones for better sound quality and a more immersive feeling during the VR experience.

Furthermore, the study included a 60-items questionnaire. After each VR exposure participants were assessed on perceived neighborhood social cohesion and perceived safety. The perceived benefits of nature, dispositional fear of crime, previous victimization, participants' subjective interpretation of the ambiguous situation and demographic variables were only assessed after the second VR exposure. These measuring scales are discussed in greater detail in the next section.

## Measuring Instruments

### *Perceived Safety*

In the beginning, participants were asked to respond to items measuring their perceived safety. This was one of the dependent variables in this study and was measured after each VR exposure. It comprised four items adopted from Austin et al. (2002), which have been used in several past studies (e.g. Baba & Austin, 1989; Keil & Vito, 1991) and were found to load on one factor in a factor analysis. Within the present study, the exploratory factor analysis (EFA) with principal axis factoring (PAF) similarly resulted in a one-factor solution. However, the item 'In this neighborhood, people really do not need to lock their doors when they leave their homes for a short period of time' shared little variance with the other items and loaded fairly low on this factor. It was decided to remove this item for exploratory analyses as its removal led to an increase in Cronbach's alpha from .67 to .72. A Cronbach's alpha greater than .70 suggests that a scale is sufficiently reliable (Tavakol & Dennick, 2011). Besides, factor analysis without this item resulted in an increased one-factor solution explaining 65.5% of the variance with an Eigenvalue of 1.96.

All items were answered on a 5-point Likert scale ranging from *strongly disagree* to *strongly agree*, a higher score representing higher perceived safety (Austin et al., 2002). See appendix A for a list of all items.

***Perceived Neighborhood Social Cohesion***

Subsequently, for the purpose of assessing participants' perceived neighborhood social cohesion (as a covariate) after each VR exposure, a brief form of the Perceived Neighborhood Social Cohesion questionnaire (P-NSC-BR) was employed. This is a validated 9-item instrument by Dupuis et al. (2015) that measures perceptions of neighborhood social resources. According to the authors, it demonstrates high internal consistency with a Cronbach's alpha of .93 and acceptable fit indices based on the outcome of a confirmatory factor analysis. A three-factor model was proposed, with items clustered along the dimensions 'trust' (items 1, 2, 3), 'attachment to neighborhood' (items 4, 5, 6), and 'tolerance and respect' (items 7, 8, 9). An example question was: 'If you were in trouble, there are a lot of people who would help you'. Answers are expressed in a 5-point Likert scale ranging from *strongly disagree* to *strongly agree* (see Appendix A).

Within the present study, an EFA with PAF (and an expected three-factor model in mind) revealed that not all items clustered along the expected dimension. Item 3 (If you were in trouble, there are a lot of people who would help you) grouped together with the attachment to neighborhood items and item 4 (Most people in this area are friendly) with those believed to make up the trust dimension. However, based on their wording it is believed that this arrangement of items is still logical. Furthermore, item 9 shared little common variance with the other items and had low factor loadings on all three factors. Without this item, an already high Cronbach's alpha only slightly increased from .85 to .86. Hence, this item was only removed for exploratory analyses. To retain the scale metric, composite scores were created by summing up all raw scores and dividing them by the number of items to obtain an average score.

***Interpretation of Ambiguous Situation***

Next, to measure the second dependent variable, that is how respondents interpreted the ambiguous situation, participants were asked to provide a story script to a scene involving an encounter between three young men in a park during night. Participants' responses were categorized into 'negative', 'neutral' or 'positive' by three independent coders. When the number of positive comments exceeded the negatively or neutrally connoted comments then the story script was coded as positive. If, on the contrary, the number of negatively connoted comments exceeded the number of positive or neutral comments the story script was coded as negative. Story scripts were coded as neutral if the number of positive and negative comments cancelled each other out or if comments were neither exactly positive nor negative. Calculating the inter-rater reliability by hand resulted in 82% agreement among the three

raters. Correcting for chance, the inter-class correlation (ICC) resulted in moderate agreement (Koo & Li, 2016) where the average measure ICC was .74 with 95% confidence interval (CI) from .62 to .83 ($F(77,154) = 3.84$, $p < .000$). Based on this outcome following analyses were conducted using the rating of the researcher.

***Dispositional Fear of Crime***

According to Gabriel and Greve (2003), there is no single way to assess someone's tendency toward dispositional fear of crime. Though what seems to play an important role is to assess the frequency with which situational fear of crime (as composed of an affective, cognitive, and behavioral facet) is experienced. Gabriel and Greve (2003) suggest a taxonomy of fear of crime measurements including items adopted from other research papers. For the purpose of this study, it was decided to include the six items clustered along the dimensions 'offence-specific/offence bundle' and 'affective/cognitive/behavior'. This variable was assessed for its moderating effects stated in H1.

As suggested in the taxonomy, the factor analysis confirmed that those items believed to represent the same facet (affective, cognitive, behavior) of situational fear of crime indeed grouped together based on their factor loadings. The scale resulted in acceptable internal reliability ($\alpha = .69$). An example item from the dimension 'offence-bundle' and assessing the cognitive facet of fear of crime was: 'How likely do you think it is that you will become a victim of crime outside (during the next twelve months)?'. These were measured on a scale from 1 to 5 where 1 means 'not at all' and 5 means either 'very likely' or 'often', depending on the phrasing of the item. Summing up all raw scores and dividing them by the number of items created composite scores.

Furthermore, it was relied on another scale derived from the Fear of Crime in America Survey (e.g. Ferraro, 1995; Ferraro & LaGrange, 1992) to add more questions asking about the fear of property and personal crimes. Within the present study all ten items – including item 1 that asked about being approached by a beggar - were summed for their general fear index ($\alpha = .89$) as well as sub-indices for the items designated as personal crimes ($\alpha = .90$; item 4, 5, 6, 7) and property crimes ($\alpha = .83$; item 2, 3, 8, 9, 10). Together they formed acceptable fit indices. These findings conform to those by Ferraro and LaGrange (1992). The ten items were rated on a scale from 1 to 5, where 1 means 'not afraid at all' and 5 means 'very afraid'. For simplicity, raw scores were added up and divided by the number of items to obtain an average fear of crime score that lies within the scale metric.

These two scales were treated separately in planned analyses, as they are believed to describe different aspects of the construct 'fear of crime'. A list of all their items can be found in Appendix A.

***Perceived Benefits of Nature***

Subsequently, participants were invited to respond to the 11-item Perceived Benefits of Nature Scale (PBNQ) by Dzhambov (2014) to test for the moderating effect stated in H3. This was identified as a valid two-factor model, where one factor represented 'well-being' and the other 'coping and relaxation' and had a correlation of 0.59. Based on the McDonald's omega coefficient of 0.90 the PBNQ also proved to be a reliable instrument. An example item was: 'I am more positive when I think of nature'. The items were assessed on a 5-point Likert scale ranging from *very uncharacteristic of me* to *very characteristic of me* (see Appendix A).

Within the present study, the outcome of a factor analysis with two expected underlying factors was similar to the one by Dzhambov (2014). Only item 5 did not show corresponding factor loadings with the items expected to load on the same factor and item 3 did not load high on either factor. The latter might be due to a difficult wording, which could have confused participants. Without this item Cronbach's alpha only slightly increased from .86 to .88, which is why it was removed for exploratory purposes but not for planned analyses. The items were comprised to form composite scores by adding up all raw scores and dividing them by the number of items.

***Previous Victimization***

Given some evidence of the impact of previous victimization on perceptions concerning fear or safety (e.g. Karakus et al., 2010; Taub et al., 1981) 'Previous Victimization' was included as a covariate in this study. Participants were invited to answer two items: (1) 'Have you or anyone close to you ever had their home broken into and/or had something stolen?' and (2) 'Have you or anyone close to you ever been attacked, mugged, or robbed while out walking?' These two items were adopted and slightly adjusted from Austin et al. (2002) who combined direct and indirect victimization into a single item based on the finding that both play a role in influencing attitudes concerning crime and safety.

Within the present study these two items correlated slightly above .30, which is the cut-off score to determine factorability according to Yong and Pearce (2013). However, since they had rather low internal consistency ($\alpha$ = .47) it was decided to only retain item 2 for exploratory analyses. Its wording is of greater relevance to the present study, which aimed to research safety perceptions outside from home in urban environments.

### *Demographic Questions*

Lastly, participants were asked to answer a number of demographic questions revolving around their age, nationality, gender, and occupation (see Appendix A).

## Procedure

Participants were invited for a 45-minute experiment to the lab and were told in advance that they would evaluate a city environment based on their experience during a VR exposure. Upon arrival, they first sanitized hands and subsequently filled in the 'Reciprocal Informed Consent Concerning Potential Viral Infection' form, the 'Viral Infection Risk Checklist', and were asked to sign an informed consent (see Appendix B). This and other measures taken by the researcher (wearing a facemask during the set-up, providing a head cover for the VR headset, cleaning the VR equipment before each experiment) were part of a safety protocol to minimize the risk of contracting Covid-19. The researcher then instructed participants on how to get inside the Virtualizer and taught them walking on the locomotion platform (see Figure 4 for the set up of the experiment). For this, a video tutorial available in the Virtualizer user instruction manual was shown and participants then had to practice walking using a test VR environment from Unity.

The actual experiment consisted of two phases. In phase A participants were told to explore the VR environment while experiencing it by daylight. All groups were exposed to the same middle-to-low socioeconomic status (SES) neighborhood featuring densely arranged apartment blocks. Only the presence and maintenance of UGS differed across the three groups. The control group was not exposed to any UGS. However, the well-maintained group was exposed to well-maintained, small-scale UGS and the uncared group to uncared UGS, such as dense and view-obstructing shrubs (see Figure 5). Besides, during the day and night exposure, the environment featured fog, a wall-graffiti in the park, roadblocks to seal off the outer circles of the city, and some urban waste (see Appendix C for a detailed project documentation including a link to a research video).

The experiment transitioned into phase B after participants filled in the first part of the questionnaire (asking about perceived safety and perceived neighborhood social cohesion) during a short break. In this phase, participants experienced the same environment depending on their group, but this time at night. They were instructed in advance to imagine that they would be on their way home after a night out. A drawing of the path participants would have to walk home was shown to them and they were told in advance to make a decision on either turning left or right once reaching a junction at the end of the street. Participants were withheld the information that on their way home they would encounter a group of young men

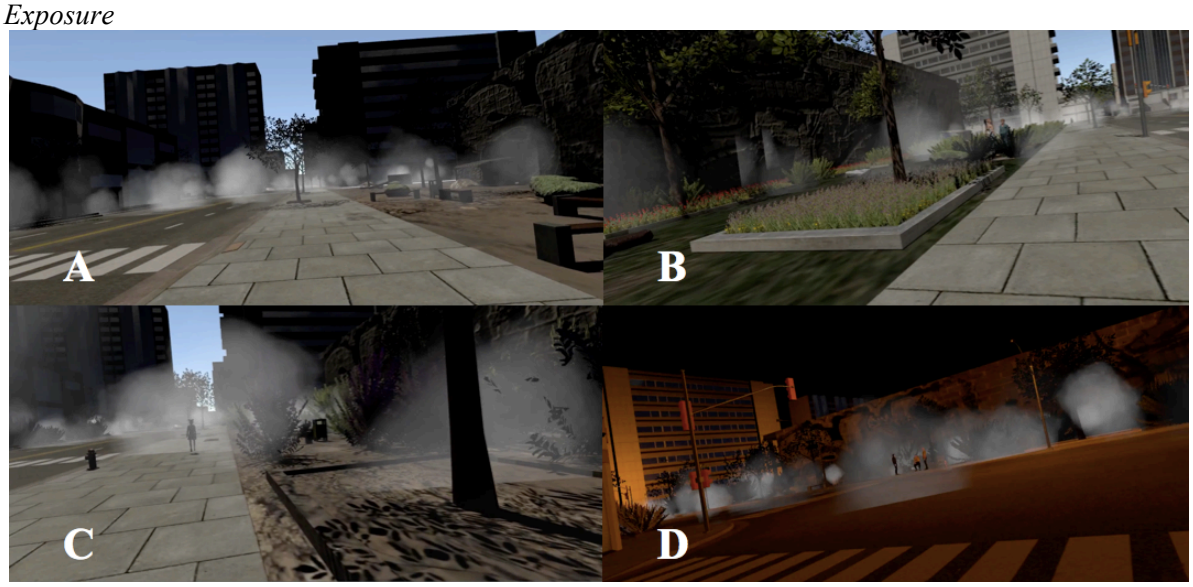
hanging out in a park which could possibly influence their path selection. If they decide to take a left turn they will walk past the men, whereas turning right will lead them away from them. The entire situation was kept as ambiguous as possible to leave room for individual interpretation and to reduce the risk of biasing participants' reactions. Hence, it was decided to avoid any active interaction with those young men within the VR experience and to choose ambiguous audio, which made it impossible to understand what the men were conversing about. The decision-making element was added as a behavioral outcome measure testing for approach versus avoidance with regard to path route selection.

After reaching the end of the second VR exposure and being released from the Virtualizer participants filled in the other half of the questionnaire and were debriefed about the true aim of the study. Finally, participants were thanked for their participation and encouraged to contact the researchers via e-mail in case of any remarks or questions.

**Figure 4**
*The Researcher Models the VR Set Up*

**Figure 5**

*Differences in the Presence and Maintenance of UGS Between Groups and the Day and Night Exposure*




*Note.* Picture A depicts the control group with no UGS. B depicts the group with well-maintained UGS. C depicts the group with uncared UGS. D exemplifies the night-exposure.

## Data Analysis

All data assessed by the questionnaire were analyzed using the computer software IBM SPSS Statistics 24. In order to test the linear regression models for a potential moderation effect of dispositional fear of crime on the relationship between well-maintained UGS and perceived safety at night (H1), the PROCESS macro for SPSS was used (Hayes, 2017). The same holds for the potential moderation effect and mediation effect tested in H3 and in H2.

Before running the statistical analyses a correlation matrix was produced to see whether there exist correlations between the independent variables (including the covariates) and dependent variables used in this study. Ruling out potentially high correlations between the considered covariates and the dependent variables helps in the interpretation of the conducted analyses and reduces problems with potentially non-randomized groups.

For the statistical analyses, it was decided to use the new statistics approach. This was based on Cumming (2013) who advocates a shift from hypothesis significance testing (confirmatory research) to greater use of an exploratory, informative approach, that considers the whole array of findings, whether significant or not. The new statistics approach refers to practices that omit any mention of statistical significance (dichotomous, black and white thinking), and instead focuses on estimation thinking and therefore the interpretation of the effect size and confidence interval (CI) (Cumming, 2013). The potential moderation effects stated in H1 and H3 were thus analyzed by interpreting two interaction plots and the

confidence intervals for the estimation statistics. For H2 relevant estimation statistics of the path regressions proposed by Baron and Kenny (1986) for mediation analysis were interpreted.

Lastly, several exploratory analyses were conducted to investigate whether one yields different outcomes using slightly adjusted scales by removing the items which shared only little common variance as mentioned in the 'Measuring Instruments' section. Furthermore, socio-demographic variables including age, gender, nationality, previous victimization, perceived neighborhood social cohesion and perceived benefits of nature were taken into account to control for confounders in the moderation and mediation analyses. Next, it was checked whether there were notable differences on perceived safety and perceived neighborhood social cohesion between the day and night exposure. Finally, it was of interest to see whether there were any notable differences between groups in the 'decision time' and the 'direction' they chose during the night exposure.

Before conducting the planned and exploratory mediation and moderation analyses it was checked for accuracy, outliers, additivity, normality, linearity, homogeneity and homoscedasticity. However, in the planned analyses all the data was taken into account, irrespective of whether there were outliers detected or not. In the exploratory analyses, emerging outliers were not taken into account.

## Results

First of all, the most interesting findings of a correlation matrix checking for correlations between independent variables (including potential covariates) and dependent variables are briefly stated. Afterwards, the planned analyses are presented in the following order: (1) two moderation analyses (using different fear of crime measuring instruments) to test for the effect of fear of crime on the relationship between well-maintained UGS and perceived safety, (2) a mediation analysis to test whether perceived safety acts as a mediator for the relationship between well-maintained UGS and interpretation of ambiguous situation, (3) a moderation analysis testing for the effect of perceived benefits of nature on the relationship between the presence of UGS and more positive interpretations of an ambiguous situation. Finally, there is a section dedicated to several exploratory analyses.

### Correlation Matrix

As can be seen in Table 2 perceived neighborhood social cohesion appears to have a moderate positive relationship with perceived safety and interpretation of ambiguous situation. Perceived safety, which is assessed as a dependent variable but also for its mediating effect as an independent variable in H2, has a moderate positive relationship with

interpretation of ambiguous situation. Other variables (including age, gender, occupation, dispositional fear of crime, perceived benefits of nature, and previous victimization) that were informative about baseline differences among respondents did not correlate highly with perceived safety and interpretation of ambiguous situation. Hence, it can be assumed that even if there were problems with non-randomized groups, it is less likely that differences among groups in these baseline characteristics have had anything to do with the observed outcomes in this study. Nonetheless, these variables and an additional one asking about participant's nationality were included in following exploratory analyses.

**Table 2**

*Means, Standard Deviations, Pearson and Eta Correlations Between Perceived Neighborhood Social Cohesion (PNSC), Perceived Safety (PS), Dispositional fear of Crime A (DFCA), Dispositional Fear of Crime B (DFCB), Perceived Benefits of Nature (PBN), Previous Victimization (PV), Interpretation of Ambiguous Situation (IAS), Age, Gender, and Occupation*

| Variable | *M* | *SD* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. PNSC | 2.38 | .63 | 1.00 | | | | | | | |
| 2. PS | 2.04 | .76 | .71 | 1.00 | | | | | | |
| 3. DFCA | 2.61 | .90 | -.12 | -.08 | 1.00 | | | | | |
| 4. DFCB | 1.95 | .60 | -.14 | -.05 | .53 | 1.00 | | | | |
| 5. PBN | 3.61 | .63 | -.09 | -.02 | .01 | .13 | 1.00 | | | |
| 6. PV | .53 | .50 | .01 | -.01 | -.01 | -.03 | .20 | 1.00 | | |
| 7. IAS | 1.50 | .77 | .50 | .41 | -.09 | -.25 | -.17 | .30 | 1.00 | |
| 8. Age | 22.27 | 3.57 | .30 | .14 | -.38 | -.28 | .23 | .23 | .19 | 1.00 |
| 9. [a]Gender | | | .21 | .20 | .33 | .36 | .14 | .02 | .27 | .06 |
| 10. [a]Occupation | | | .04 | .12 | .21 | .12 | .07 | .01 | .10 | .38 |

*Note.* [a]Two-level variables were created for gender and occupation. An outlier that did not fit into either category identified for occupation was excluded from this analysis. Eta statistics using crosstabs were calculated to determine the association strength between a nominal and interval scaled variable.

## Planned Analyses

### *Hypothesis 1*

To test H1 by means of a moderation analysis, an interaction term of the UGS group variable (consisting of three levels: control (no UGS), uncared UGS, and well-maintained UGS) and fear of crime was created and the variables were mean-centered to prevent potentially problematic high multicollinearity (Aiken & West, 1991). The UGS group variable was dummy coded beforehand, with the control group as the reference group.

At first sight, the interaction plots in Figure 6 reveal that in all groups perceived safety was rather low at any given level of fear of crime. Yet, looking at between-group comparisons it appears that the well-maintained UGS group scored on average the highest on perceived safety at night, but only when fear of crime was low. At high levels of fear of crime this group

was on average the lowest on perceived safety. Although a negative relationship was expected, it was remarkable that of the three different groups the well-maintained UGS group scored the lowest on perceived safety the higher the fear of crime among participants. This stays in contrast to what had been hypothesized. Unlike expected, perceived safety increased and was on average the highest among the uncared UGS group at high levels of fear of crime. Furthermore, it was noteworthy that there was almost no difference observed in the control group (see left plot of Figure 6). The interaction plot on the right, depicting the other fear of crime measure, shows a similar result. Only this time the differences between the groups on perceived safety at different levels of fear of crime decreased. Furthermore, fear of crime had almost no effect on the relationship between uncared UGS and perceived safety, while there was a slight increase in perceived safety when fear of crime was high in the control group.

The findings depicted in Table 3 do not align with what had been hypothesized either. The point estimates for the given interaction terms are relatively small and the CIs are lengthy. All CIs include zero more or less at the center of the interval (only for the well-maintained group zero falls within the upper bound of the CI). This speaks against the likelihood of a moderating effect of fear of crime. As zero falls within (especially at the center) the CI, it cannot be ruled out that the true effect is likely different from no effect; lengthy CIs imply greater margin of error (MOE) and therefore less precise point estimates (Hazra, 2017; see Table 3). Hence, even for the well-maintained group the point estimate does not reliably predict the true effect size. Lastly, due to overlaps in the CIs between groups it is less likely that the groups actually differ in perceived safety at any given level of fear of crime. These observations do not align with H1.

**Figure 6**

*Interaction Plots Depicting How UGS (Three Levels: Control (No UGS), Uncared UGS, and Well-Maintained UGS) and Fear of Crime are Related to the Respondents' Perceived Safety at Night*

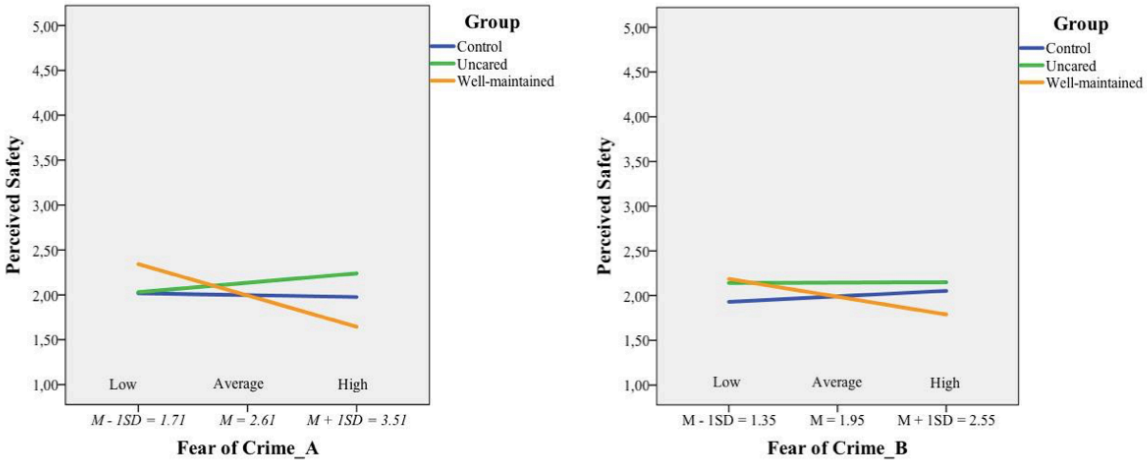


**Table 3**
*Confidence Intervals for Moderation Analyses of Fear of Crime Measurements (M), UGS (IV), and Perceived Safety at Night (DV)*

| | | *95% Confidence Interval for b* | |
|---|---|---|---|
| [a]Variable interaction | *b* | *Lower Bound* | *Upper Bound* |
| [b]X1 x Fear of Crime_A | .14 | -.30 | .58 |
| [b]X2 x Fear of Crime_A | -.36 | -.84 | .12 |
| [c]X1 x Fear of Crime_B | -.10 | -.86 | .67 |
| [c]X2 x Fear of Crime_B | -.43 | -1.11 | .25 |

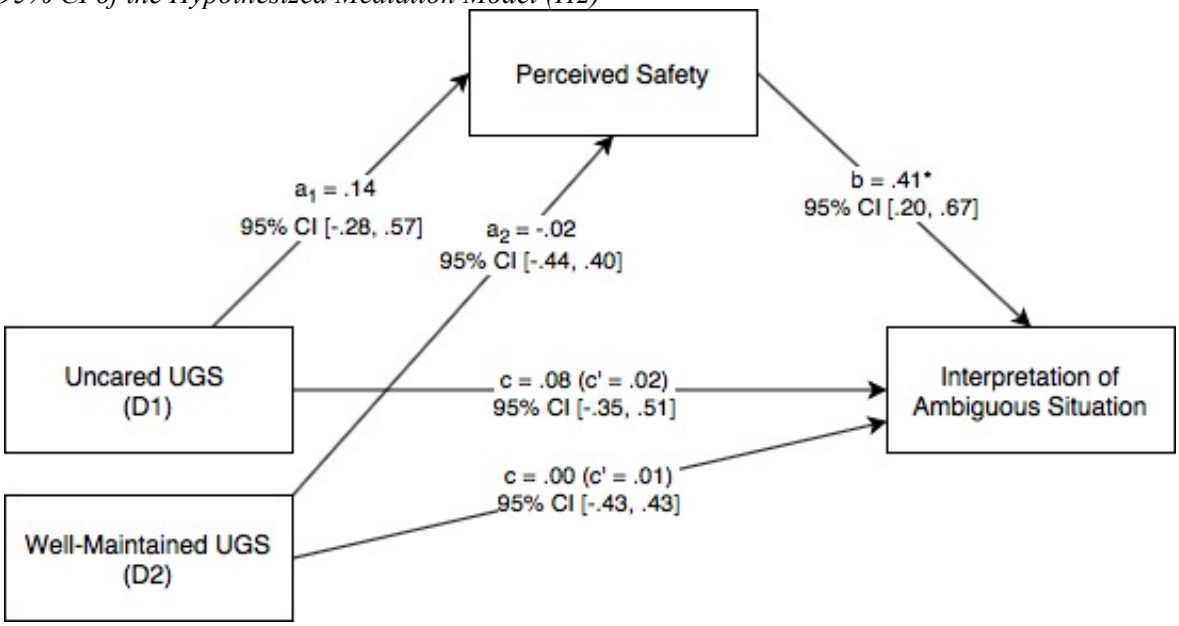
*Note.* [a]X1 and X2 correspond to the uncared UGS and the well-maintained UGS group respectively and the control group is the reference group. [b]Without interaction: $R^2$ = .07, $F(5, 72) = 1.07$; Interaction: $\Delta R^2$ = .05, $\Delta F(2, 72) = 2.07$. [c]Without interaction: $R^2$ = .03, $F(5, 72) = .49$; Interaction: $\Delta R^2$ = .02, $\Delta F(2, 72) = .82$.

### *Hypothesis 2*

Baron and Kenny's (1986) regression approach was used to test the mediation model in H2. The results of the different regression pathways revealed the following. The interpretation of the ambiguous situation in the well-maintained group as compared to the control group was not found to be more positive when the moderator 'perceived safety' was added to the model (direct effect c'). The result was the same without perceived safety in the model (total effect c) (see Figure 7). Furthermore, for this group comparison (well-maintained versus control) perceived safety did not mediate the relationship between well-maintained UGS and the interpretation of the ambiguous situation, a*b = -.01, 95% *BCa CI* [-.16, .17]. It cannot be predicted that the true effect size is different from no effect as the CI contains zero at its center, $b^2$ = .01, 95% *BCa CI* [-.21, .23]. H2 needs to be rejected. Since there was no moderation effect found for H1, a moderated mediation effect can be ruled out. There is no reason to believe that the indirect effect of well-maintained UGS on the interpretations of ambiguous situation through perceived safety might potentially differ as a function of fear of crime. For all steps of the mediation analysis see Table 4.

**Figure 7**

*Mediation Model With Path Estimates (Including Direct (C'-Path) and Total Effect (C-Path)) and 95% CI of the Hypothesized Mediation Model (H2)*




*Note.* *As perceived safety increases, the interpretation of ambiguous situation increases (becomes more positive) as well.

**Table 4**

*Steps of the Mediation Analysis of Perceived Safety on the Relationship Between Well-Maintained UGS and Interpretation of Ambiguous Situation*

| | | | | | | *95% Confidence Interval* | |
|---|---|---|---|---|---|---|---|
| | $R^2$ | *F* | *b* | *SE* | *t* | *LLCI* | *ULCI* |
| a-path | .01 | .36 | | | | | |
| D1 | | | .14 | .21 | .68 | -.28 | .57 |
| D2 | | | -.02 | .21 | -.09 | -.44 | .40 |
| b-path | .16 | 4.87 | | | | | |
| Perceived Safety | | | .41* | .11 | 3.79 | .20 | .63 |
| c-path | .00 | .08 | | | | | |
| D1 | | | .08 | .21 | .36 | -.35 | .51 |
| D2 | | | .00 | .21 | .00 | -.43 | .43 |
| Direct (c'-path) | .16 | 4.87 | | | | | |
| D1 | | | .02 | .20 | .09 | -.38 | .42 |
| D2 | | | .01 | .20 | .04 | -.39 | .40 |
| Indirect (a*b) | | | *b* | *BootSE* | | *BootLLCI* | *BootULCI* |
| D1 | | | .06 | .09 | | -.12 | .25 |
| D2 | | | -.01 | .08 | | -.16 | .17 |

*Note.* The UGS variable was dummy coded with uncared UGS (D1), well-maintained UGS (D2), and control as the reference group.

### *Hypothesis 3*

Again, an interaction term of the experiment group and perceived benefits of nature was created and the variables were mean-centered to prevent potentially high

multicollinearity. Similar to the previous moderation analysis (H1), the experimental groups were dummy coded beforehand, with the control group as the reference group.

Unlike previous expectations, Figure 8 shows that for both UGS groups the interpretations of the ambiguous situation became more negative as perceived benefits of nature increased. However, the observed variance in respondent's interpretations at different levels of perceived benefits of nature was greater in the uncared UGS group, as compared to the two other groups. It seems that only for this group the interaction with the moderator led to an added amount of variance in the outcome variable, as can be seen from the relatively steep slope (see Table 5). Yet, the length of the CI indicates that there is uncertainty with regard to how precise the estimate ($b$ = -.86) is in predicting the true change in the outcome variable. Furthermore, the upper bound of the CI is relatively close to zero and therefore the true change might be close to zero too. The well-maintained UGS and the control group, however, interpreted the ambiguous situation on average in more negative to neutral terms, both at low and high levels of the moderator. Hence, responses of these two groups were more alike, and also did not vary greatly with an increase or decrease in the moderator.

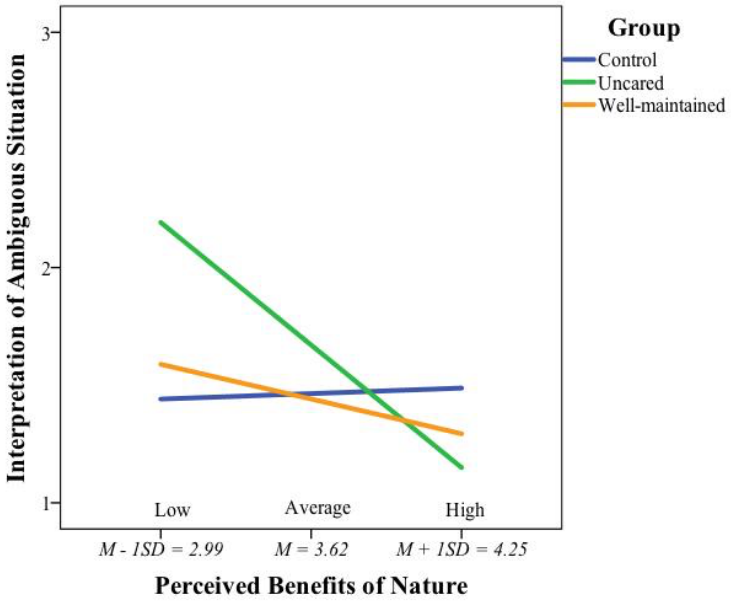
When comparing the uncared UGS group and the control group (reference group), it appears that the interpretation of the ambiguous situation may actually only be different at lower levels of perceived benefits of nature. Put differently, only at low levels of the moderator ($M - 1SD$ = 2.99), the interpretations given by respondents of the uncared UGS group are presumably different (in this case more positive) from the control group. Yet again, as the CI ranges from .11 to 1.39 the estimated difference in increase in positivity of the interpretations ($b$ = .75) between these two groups is not precise. With the lower end of the CI being close to zero, one cannot conclude with great certainty that the true difference between these groups would actually be much greater than zero.

To sum up, two conclusions can be drawn. First, one of the UGS groups (the uncared UGS) appears to have on average more positive interpretations of the ambiguous situation as compared to the control group, but only at lower levels of perceived benefits of nature. However, it must be noted that even though labeled as 'low' in Figure 8 a score of 2.99 equals neither low nor high perceived benefits of nature on a 5-point Likert scale. Second, the moderating effect of perceived benefits of nature on the relationship between uncared UGS and interpretations of ambiguous situations is not in the expected direction. Yet, due to lengthy CIs and therefore an uncertainty with regard to the precision of the estimates, one must be cautious in making inferences about the size of the observed moderating effect and the amount of variance observed in the positivity of interpretations at low levels of the

moderator. This outcome does not align with H3, which presumed that in both UGS groups respondents would have more positive interpretations of the ambiguous situation, especially at higher levels of perceived benefits of nature.

**Figure 8**

*Interaction Plot Depicting How UGS (Three Levels) and Perceived Benefits of Nature are Related to the Respondents' Interpretation of the Ambiguous Situation*




*Note.* 1 represents a negative, 2 a neutral and 3 a positive interpretation

**Table 5**

*Confidence Intervals for Moderation Analyses Perceived Benefits of Nature (M), UGS (IV), and Interpretation of Ambiguous Situation (DV)*

| | | *95% Confidence Interval for b* | |
|---|---|---|---|
| [a]Variable interaction | *b* | *Lower Bound* | *Upper Bound* |
| [b]X1 x Perceived Benefits of Nature | -.86 | -1.53 | -.18 |
| [b]X2 x Perceived Benefits of Nature | -.27 | -.95 | .41 |

*Note.* [a]X1 and X2 correspond to the dummy coded uncared UGS and the well-maintained UGS group respectively and the control group is the reference group ($N = 78$). [b]Model without interaction term: $R^2 = .12$, $F(5, 72) = 1.88$; Interaction: $\Delta R^2 = .08$, $\Delta F(2, 72) = 3.22$.

## Exploratory Analyses

### *Planned Analyses with Adjusted Scales*

Based on the results of the factor analyses under 'Measuring Instruments' the moderation and mediation analyses were repeated using adjusted scales and excluding identified outliers. However, for all analyses testing the three hypotheses' results did not change notably (see Appendix D for a detailed account of the analyses including statistics).

### *Considering Covariates*

To further increase the accuracy of the previous analyses several potential covariates were taken into account, including age, gender, nationality, previous victimization, perceived neighborhood social cohesion and perceived benefits of nature. Again, identified outliers were excluded from the analyses. This section solely provides a brief summary of the key findings. See Appendix D for a detailed description of the analyses, including all relevant statistics and figures that aid interpretation. For H1 and H2 the results did not change notably after adding covariates to the model. The interaction term between fear of crime and the experiment groups did not lead to an added amount of variance in perceived safety (H1). With regard to H2 there was still no indirect or mediation effect found of perceived safety on the relationship between well-maintained UGS and interpretations of ambiguous situations. However, for the moderation analysis as specified in H3, the outcome slightly changed. With the covariates included in the model, the interaction term between the uncared UGS group and perceived benefits of nature did not lead to an added amount of variance in the interpretation of the ambiguous situation anymore.

Other notable findings include the following. First of all, findings repeatedly suggested that as perceived neighborhood social cohesion increases, perceived safety increases as well. This fits with the moderately positive correlation found between these variables (see Table 2, p. 19). Furthermore, findings repeatedly pointed towards a main effect between perceived neighborhood social cohesion and interpretation of the ambiguous situation. The same holds for previous victimization and interpretations of ambiguous situation. Hence, there is evidence that as perceived neighborhood social cohesion increases, the interpretations of ambiguous situation become more positive. Respondents who experienced previous victimization (coded as 0 = no, 1 = yes) have more positive interpretations of the ambiguous situation as well. However, correlation analyses revealed only a moderately strong correlation between social cohesion and interpretations of ambiguous situation and a weak correlation between previous victimization and the same variable (see Table 2, p. 19).

### *A Mediation Model with Perceived Neighborhood Social Cohesion as Mediator*

The moderately positive correlation between perceived safety and perceived neighborhood social cohesion as well as exploratory findings that were indicative of a main effect between these two variables called for another exploratory analysis. It was of interest to explore whether there exists a potential mediation effect of perceived neighborhood social cohesion on the relationship between well-maintained UGS and perceived safety. However,

there was no indirect effect found, a*b = -.01, 95% *BCa CI* [-.31, .28]. It cannot be predicted that the true effect size is different from no effect as the CI contains zero at its center, $b^2$ = -.01, 95% *BCa CI* [-.39, .36].

***Day Vs. Night Exposure***

On average there was a slight increase in perceived safety from day to night exposure for the control group ($M_{difference}$ = .11, *SD* = .72), while there was a slight decrease in perceived safety for the uncared UGS ($M_{difference}$= -.13, *SD* = .84) and the well-maintained UGS group ($M_{difference}$ = -.19, *SD* = .62). However, judging from the length of the 95% CIs for these estimates and a small partial eta squared effect size the observed increases or decreases in perceived safety are not big enough to rule out that there was no difference in perceived safety between day and night within a group, $F(2,75) = 1.21$, $\eta_p^2 = .031$. Furthermore, between groups, it seems unlikely that the above difference scores diverge enough to conclude that in one group the perceived safety increased or decreased more from day to night exposure as compared to another group. Looking at the grand means for all groups, it appears that respondents had on average rather low perceived safety in both phases of the experiment ($M_{Day}$ = 2.12, SD = .07; $M_{Night}$ = 2.04, SD = .09).

For perceived neighborhood social cohesion there was on average a slight decrease from day to night exposure for the control ($M_{difference}$ = -.03, *SD* = .64), the uncared UGS ($M_{difference}$ = -.02, *SD* = .54) and the well-maintained UGS ($M_{difference}$ = -.14, *SD* = .43) group. Yet again, these differences from day to night exposure within a group are not big enough to rule out that no difference actually occurred at the 95% *CI*, $F(2,75) = .37$, $\eta_p^2 = .010$. Between groups, the difference score (indicating how perceived neighborhood social cohesion changed from day to night) did not differ greatly based on that the 95% CIs for all possible comparisons include zero and overlap between groups. The grand means reveal that the groups scored on average around low to medium perceived neighborhood social cohesion in both phases of the experiment ($M_{Day}$ = 2.44, SD = .05; $M_{Night}$ = 2.38, SD = .07).

***Further Group Differences***

There were no notable group differences in respondents average decision time (in seconds) to go either left or right at the junction during the second phase of the experiment as the CIs between groups overlap to a great extent (see Table 6). At a 95% CI the chance that for a randomly selected pair of individuals the average decision time would be notably longer in one group as compared to another was 1.1%, $F(2,75) = .43$, $\eta_p^2 = .011$. Furthermore, in all groups (*n* = 26) the pattern for the direction respondents chose to go was the same. In 26.9%

of the cases respondents chose to go left, whereas in 73.1% they chose the right direction and therefore not passing the group of young adults.

**Table 6**

*Means and Estimated Confidence Intervals for Group Differences on Decision Time*

| | | *95% Confidence Interval for Estimates* | |
|---|---|---|---|
| Group | [a]*M* | *Lower Bound* | *Upper Bound* |
| Control (no UGS) | 14.66 | 11.11 | 18.21 |
| Uncared UGS | 12.36 | 8.82 | 15.91 |
| Well-maintained UGS | 13.20 | 9.65 | 16.75 |

[a]*SD* = 1.78

## Discussion

The goal of this research was to examine the extent to which the presence and maintenance of UGS affect perceptions of safety and how people interpret an ambiguous situation. It builds upon previous studies, which mostly found a correlation between UGS, crime and the fear of crime, but found little evidence for causation (Kondo et al., 2017). Determining specifically whether well-maintained UGS cause people to feel safer and to frame ambiguous situations in more positive terms (compared to uncared or no UGS) can have important implications for crime prevention by providing recommendations for more effective urban planning efforts. Based on former research and criminology theories it was predicted that the group featuring well-maintained UGS would score higher on perceived safety at night compared to the two other groups, and that this effect is moderated by dispositional fear of crime (H1). Moreover, it was hypothesized that perceived safety mediates the presumed relationship between well-maintained UGS and positive interpretations of ambiguous situations (H2). Furthermore, the presence of UGS (whether uncared or well-maintained) was expected to cause more positive interpretations of the ambiguous situation compared to when there are no UGS, and that this effect becomes stronger as perceived benefits of nature increases (H3).

The results of this study are not in line with the proposed hypotheses. The groups do not seem to differ greatly in their perceived safety, irrespective of whether participants were low or high in dispositional fear of crime. Furthermore, the interpretations of the ambiguous situation were not found to be more positive when UGS were well-maintained compared to the absence of UGS and perceived safety did not play a mediating role in this regard. Unexpectedly, the presence of uncared UGS seemed to evoke more positive interpretations of the ambiguous situation as compared to the absence of UGS, but only at lower levels of perceived benefits of nature. Attitudes towards nature moderated participants' interpretations

of the ambiguous situation in this group, however not in the expected direction. The higher the perceived benefits of nature the more negatively participants framed the situation of the three young adults. Yet, the moderating effect disappeared when adding a number of covariates to the model. Hence, this effect could be explained by a shared variance of some or the interplay of all confounding variables in the model than either one alone. Furthermore, adding more variables to the model could also have had an influence on the power. In sum, these findings predominantly suggest that it does not make a difference whether UGS are well-maintained, uncared or present at all, in how safe people feel and how they frame social situations in their immediate physical environment.

The results stay in contrast with other research findings and criminology theories derived from literature. First of all, previous studies found that an open environment (Stamps, 2013), featuring UGS which signal an image of civility and maintenance (Garvin et al., 2013; Branas et al., 2018) and which do not block the view (Campagnaro et al., 2020) lead to greater perceived safety. This positive effect of well-maintained, small-scale UGS on perceived safety was even found in poor neighborhoods. For instance, studies that assessed the effects of vacant-land restoration showed that the greening and cleaning of vacant-lots, typically found in disadvantaged neighborhoods, contributed to a decrease in crime rates and increase in feelings of safety (Garvin et al., 2013; Branas et al., 2018). Contrary, “when vegetation becomes dense enough to obstruct a person's view, the result is often a sense of discomfort or even fear” (Jiang et al., 2014, p. 34). For instance, specific to green space enclosure, a study by An et al. (2004) showed that both frontal brain activity and pulse rate, which are indicative of tension and fear, increased when viewing sceneries featuring dense forest vegetation. Similarly, a study by Jorgensen et al. (2002) found that a landscape arrangement where trees are lined up on both sides of the path intensified the negative effect of dense vegetation on perceived safety more than when trees were only found on one side. Moreover, vegetation that is poorly maintained can signify disorder and a lack of social control (Wolfe & Mennis, 2012), which according to the broken windows theory increases the fear of crime (e.g. Jiang et al., 2017). Hence, these findings suggest that visual landscape properties such as well-maintained, small-scale UGS as opposed to dense, uncared UGS, contribute to higher perceived safety as was expected in H1.

One explanation for why this result was not found within the present study might have to do with the study design. Similar to other studies (e.g. Lis et al., 2019), the present study takes into account that the influence of vegetation on perceived safety varies depending on a number of spatial attributes, such as the composition, the number of UGS, their density, and

their state of upkeep. However, in addition to visibility attributes, perceptions of safety also vary depending on the situated context (Tabrizian et al., 2018). As this study did not simply compare photos of landscapes, like other studies did (e.g. Lis et al., 2019), but provided an immersive walking experience through simulated neighborhoods, any manipulation of UGS has to be considered with respect to this setting.

Perhaps the novelty effect of combining VR technology with the locomotion platform of the Virtualizer was overshadowing the manipulation of UGS, so that participants did not take in the environmental cues. However, literature suggests that VR environments are suitable for environmental evaluations, participatory planning, and analyzing cognitive behavior in urban spaces (Jamei et al., 2017; Van Dongen & Timmermans, 2019). For instance, in a study by Ozbil et al. (2016) VR was used to study the effect of spatial arrangement on pedestrian path selection. Similarly, a study by Hackman et al. (2019) assessed affective responses to the experience of either being in a simulated disadvantaged or affluent neighborhood. Furthermore, a virtual world has the ability to shield people from all real-world visual input. It can engulf them in an illusion of actual presence in the virtual environment and to experience this place and everything that is happening inside as being real (Van Gelder et al., 2013; Slater & Sanchez-Vives, 2014)

Hence, a more plausible explanation might be that the well-maintained UGS used in this study were not strong enough to wash away the negative impressions evoked by other environmental cues seen or heard while walking through the neighborhood. Alternatively, the presence of well-maintained UGS in an otherwise ill-kept neighborhood could have evoked a sense of mismatch and therefore an eerie feeling that something is not quite right. As mentioned, perceived safety is argued to be a complex phenomenon that is affected by the interaction of the social context, such as the presence of people, physical attributes and sound features surrounding environments (Luo et al., 2020). Hence, neighborhood renovation projects, such as those rooted in CPTED principles, tend to focus on the interaction of several design measures to target different aspects that influence neighborhood satisfaction and security. These include lighting and street patterns to increase natural surveillance, physical barriers (fences) and security systems (CCTV) for access control, community space to increase activity and involvement in neighborhood renovation leading to a sense of territoriality, and environmental upkeep to increase an image of civility and maintenance (Lee et al., 2016). This study, however, featured a neighborhood with relatively poor quality of housing, poor street-lighting and ambivalent sound at night, littering, graffiti, and fog (both during day and night). Furthermore, there were little signs of living due to the lack of lighting

in houses at night and limited pedestrians walking around during day. Possible evidence for a generally poor neighborhood quality were exploratory findings that revealed on average a low perceived safety and low to medium perceived neighborhood social cohesion regardless of the time of day or the participants experimental group. Hence, it seems that the well-maintained UGS were not strong enough to wash away the negative effects of the poor neighborhood quality to positively impact safety feelings. Alternatively, it is possible that in a desolated, abandoned neighborhood the well-maintained UGS looked all the stranger and therefore aroused an odd feeling which might explain the counter-intuitive finding of the higher the fear of crime the lower the perceived safety in the well-maintained group.

Conversely, the uncared UGS might have been more in line with the rest of the environment, which is why there was less variance in perceived safety depending on the level of fear of crime. Safety feelings were in general rather low at any level of fear of crime in this group as well as the control group. Hence, the green spaces alone might not have made a great difference but it was more the joint influence of an overall disturbing neighborhood ambience. In any case, these assumptions would need further inspection in future research.

The explanations above might also partially count for why the well-maintained UGS in this study did not cause participants to frame the ambiguous situation in more positive terms as compared to the other groups. Conforming with the routine activity theory, previous studies postulate that UGS lead to increased desirability of using public space, which cultivates social cohesion as outdoor activities afford opportunities for community bonding, and at the same time increases natural surveillance through more ‘eyes on the street’ (e.g. Donovan & Prestemon, 2012; Garvin et al., 2013). As previously mentioned, neighborhoods that are perceived as high in social cohesion are thought to be the ones where people feel the safest and most comfortable to walk (Jennings & Bamkole, 2019). Hence, perceived social cohesion is one pathway through which UGS are thought to have a positive effect on perceived safety. Logically then, it follows, that as people come to form positive associations with a place, such as it being high in social cohesion and therefore a safe environment, they should also frame any social situations occurring in this place in more positive terms. In line with this, exploratory findings revealed a positive association between social cohesion and perceived safety, as well as social cohesion and interpretation of the ambiguous situation. However, contrary to what is suggested from the literature there was no mediation effect found of perceived neighborhood social cohesion on the effect of UGS on perceived safety. On average, perceived neighborhood social cohesion was relatively low in all groups and during both day and night exposure.

Moreover, affirmative of negative environmental perceptions was the result that the majority of participants, regardless of their group, chose to go right and therefore the path leading away from the young adults. Again, the well-maintained UGS might not have been strong enough to overshadow the negative effects of other spatial characteristics and to foster an impression of high social cohesion in the neighborhood, thereby leading to a greater sense of safety and subsequently more positive interpretations of the ambiguous situation. Similarly, the perceived mismatch of well-maintained UGS in an otherwise abandoned, desolated neighborhood could have aroused feelings of suspicion which influenced participants to choose the path leading away from the group of men. The study by Hackman et al. (2019), found differences in affective and physiological responses after VR exposure to an affluent or disadvantaged neighborhood. Comparing their study to the current one, it becomes apparent that the affluent neighborhood presented differed as the authors focused on the interaction of only affluent features and did not combine well-kept UGS with other features implying social and physical disorder. Furthermore, there were more pedestrians present from which to make inferences about social cohesion.

Another counter-intuitive result was that the presence of uncared UGS leads to more positive interpretations of the ambiguous situation, but only at lower levels of perceived benefits of nature. Perhaps a similar explanation could be considered as the one discussed earlier. Among those who are less concerned about the beauty of nature the interpretations of the ambiguous situation were more positive as their social evaluations depend less on a perceived environmental match or mismatch. However, for those who highly appreciate nature and its effects on environmental perceptions, any interaction occurring in an environment of poor quality (featuring uncared UGS), cannot be framed in positive terms, as this would create a mismatch between perceptions of physical features of the environment and social evaluations occurring within this environment. Similarly, when appreciation of nature is low, people do not care so much about the beauty of nature and the nuances that other people see in different types (like differences in maintenance) may not influence their perceptions that much but the presence per se is more important. Yet, for those who highly value the beauty of nature a lack thereof will arouse their attention and likely lead to more negative environmental perceptions and to frame any situations occurring in this environment in less positive terms. As previously mentioned, people's perceptions and behaviors are shaped in ways that conform to the meanings they associate with objects in their environment (Van Rompay et al., 2015).

Interestingly, the uncared UGS group included the highest number of participants with previously experienced victimization and the highest mean score on perceived safety. Hence, another possible explanation for why interpretations of the ambiguous situation in this group were more positive (at least at lower levels of perceived benefits of nature) could be that prior experiences with victimization actually lead to a lower sensitivity to risks. Yeater et al. (2010) found that women with prior victimization history have a higher threshold for perceived risk (they need more evidence of risk to judge a situation as unsafe) and therefore might be more inclined to think of situations as less dangerous than they actually are. Perhaps the situation with the young adults in this study was not fearful enough to actually elicit an anticipation of danger. This would also explain the association found between previous victimization and more positive framing of the ambiguous situation. However, increasing the fearfulness of the experimental manipulation in future studies might raise ethical concerns. Certainly, the discussed assumptions require further investigation.

**Strengths**

A particularly strong point of this study was the use of VR technology. Due to its potential to fully immerse and have people interact with simulated environments that closely resemble the real world, VR technology is considered an effective tool to enhance public participation in planning and design (Jamei et al., 2017). Moreover, "VR creates a link between theoretical and practical frameworks by employing the cognitive psychology and architectural design, as well as urban design" (Jamei et al., 2017, p. 13). Hence, this study benefitted from an experiential approach that connects theory and practice by analyzing theoretical concepts through real-time direct experience, which proves highly practical and time-efficient, especially in the field of urban planning.

Furthermore, VR is a tool that affords a highly controlled setup. Virtual representations of city and street environments can be adapted in ways to fit the personal needs. For instance, game development platforms, such as Unity, provide the possibility to experiment with a wide array of supported techniques that can be used to render any visual, auditory or other interactive content of a simulated environment (Jamei et al., 2017). In this study, the VR environments were designed in a purposeful way in which certain characteristics of the neighborhood were held constant throughout all groups and only the presence and maintenance of UGS differed, to be able to link cause and effect through treatment manipulation.

**Limitations and Future Directions**

In addition to the strengths, this study also has some limitations that are related to the study design. Even though VR technology is found to be a promising tool to create realistic virtual city walkthroughs (Ghani et al., 2017) there might have been an issue with the level of authenticity in this study. Participants frequently reported that the neighborhood seemed abandoned due to the limited presence of pedestrians and this made it difficult to answer questions about neighborhood social cohesion. The lack of dynamic and interactive avatars, which adds liveliness to a simulated environment, is a frequent issue identified in other case studies (Ghani et al., 2017). This possibly hindered participants, especially after the day exposure, to make inferences about the social fabric of the neighborhood. Adding more pedestrians and other sources that increase the experiential quality of the simulation in future studies could also reduce a possibly experienced mismatch of auditory and visual content. The day exposure featured suburban sounds, such as driving cars and playing children, even though participants did not encounter either during their neighborhood walkthrough. Furthermore, while the VR environments included auditory and visual content, they did not take into account olfactory or tactile appreciation of UGS, potentially adding to the nature experience. For instance, touching soft-textured plants can contribute to a sense of comfort and peace of mind (Daneshnejad & Matin, 2015), and being able to smell UGS was found to play an important role in environmental preferences as well (Chen et al., 2009). In general, the more multisensory and interactive one designs the VR environment, the higher the experience of immersion and realism.

Another important limitation was a large reliance on self-report scales. Perceptual processes, such as those related to safety and neighborhood social cohesion, might also be influenced by the subconscious (Rezvanipour et al., 2021). The study included some behavioral outcome measure by capturing participants' decision time and path selection at the junction where they encountered the ambiguous situation. However, future studies could possibly benefit from utilizing additional behavioral outcome measures, which for instance focus on analyzing the influence of well-maintained UGS on pro-social behaviors. Likewise, measures of physiological stress, such as pulse rate or skin conductance reactivity, or measures of attentional focus, such as eye tracking, could prove valuable in order to more robustly examine perception-related constructs.

Adding these additional measures could be especially of interest in further research on perceived neighborhood social cohesion. Perceived neighborhood social cohesion was not found to be a mediator between well-maintained UGS and safety in this study. However, the given direct effect of social cohesion on safety and positive social perceptions invites to

further study the influences of this construct. Other studies declared the social cohesion between residents and users of an area to be a preventive factor that protects in the same way as urban design, because people take greater responsibility for their community (Saville & Cleveland, 2003a, 2003b, 2008). In areas that are perceived to be high in social cohesion residents have a strong sense of shared expectations for control and a willingness to intervene on behalf of the common good, for instance to reduce crime (Sampson, 2012).

Furthermore, future studies could benefit from increasing the sample size. Including more participants will increase the precision and reliability of the estimate of a population parameter and this is reflected in a narrower CI (Hazra, 2017). The width of the CI is thus inversely related to the sample size. In this study there was a large width observed in the CIs, which is indicative of less precise estimates of the population parameter and possibly hints at including larger amounts of data if the study were to be repeated.

Lastly, this study was mainly representative of the perceptions and decision making of Germans and Dutch citizens. The applicability of the study findings therefore should be considered for now at best to be limited to the Dutch and German population. Even though adding nationality as a covariate did not lead to differences in the outcome of this study, a sample that is representative of more cultures could be interesting for several reasons. First of all, future research could aim at the effect of global differences on the value people attribute to the UGS design. As previously mentioned, people's perceptions are shaped in ways that conform to the meanings they associate with objects in their environments (Van Rompay et al., 2015) which developed through personal experience (Piga & Morello, 2015). Hence, people from less affluent countries, as those presented in this study, might have perceived the VR environments differently based on their preferences and experiences with UGS. Furthermore, on a more regional level, perceptions and preferences for urban design might also vary depending on previous experiences. Those who grew up in more rural areas might feel more at ease and prefer UGS that closely resemble wilderness, while city dwellers might be more familiar with and therefore have a preference for maintained, small-scale UGS. Hence, future research could aim at differences between regions and countries and how this affects perceptions of an environment. Alternatively, it could also be interesting to see how perceptions among a homogeneous sample change when adding well-maintained UGS that make more of an impression. Even though research found that people have a high preference for environments featuring flowerbeds of different colors (Van Dongen & Timmermans, 2019), the level of maintenance of the well-kept UGS in this study might have been too familiar in order to be noticed by the predominantly Dutch and German participants. Hence,

future studies could aim at adding more embellishment or choosing relatively novel types of UGS, such as vertical greenery, and examine their capability to wash away the negative effects of other neighborhood characteristics.

**Implications and Conclusion**

This study aimed to explore the extent to which the presence and maintenance of UGS has an effect on perceptions of safety and how people interpret an ambiguous situation. Even though the findings stay in contrast to what was expected, they have some implications for theory and practice. First of all, the degree to which well-maintained UGS affect perceptions of safety and induces people to frame an ambiguous situation in more positive terms seems to depend on the situated context. A situational setting, which also features neighborhood characteristics indicative of social and physical disorder, calls for particular attention to the level of maintenance and visibility of UGS to overshadow the negative effects of other environmental cues. Furthermore, the study findings could also point towards focusing on the interaction of several social or physical features of the built environment. Well-maintained UGS alone might not be enough to considerably influence cognitive responses comprising perceptions of safety and situation construal. Hence, researchers can build on this knowledge and focus on improving the research design by adding embellishment that will further increase the visibility and level of maintenance of UGS. Alternatively, they can combine UGS with additional urban design measures that will enhance positive environmental perceptions. Further investigation is needed to see whether this as well as increasing the sample size changes the study's outcome.

Concluding, this study directs future research in that it provides suggestions under which conditions UGS might be more effective in positively influencing perceptions of safety and interpretations of ambiguous situations. Future research that takes these suggestions into account and verifies the reasons for the absence of an effect (whether it was indeed the design of the environments or for instance the use of a student sample) could possibly guide urban planning efforts in providing recommendations for more effective crime prevention strategies. Furthermore, since UGS have health-promoting functions (e.g. Bogerd et al., 2018; Ulrich, 1984) and mitigate the urban heat island effect (Soltani & Sharifi, 2019), gaining deeper insights from future research might also help urban planners to include considerations in future planning interventions that improve the mental-restoration and the thermal comfort experienced in a place. Hence, this study adds to existing literature, which paves the way for research that aims to explore win-win situations between sustainability and the perceived quality of experience of urban space.

## References

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions*. Thousand Oaks, CA: Sage.

An, K. W., Kim, E. I., Jeon, K. S., & Setsu, T. (2004). Effects of forest stand density on human's physiopsychological changes. *Journal of the Faculty of Agriculture Kyushu University, 49*(2), 283-291.

Austin, D. M., Furr, L. A., & Spine, M. (2002). The effects of neighborhood conditions on perceptions of safety. *Journal of Criminal Justice, 30*(5), 417–427. https://doi.org/10.1016/S0047-2352(02)00148-4

Baba, Y. & Austin, D. M. (1989). Neighbourhood environmental satisfaction, victimization and social participation as determinants of perceived neighbourhood safety. *Environment and Behaviour, 21*(6), 763-780. https://doi.org/10.1177/0013916589216006

Baldock, K. L., Paquet, C., Howard, N. J., Coffee, N. T., Taylor, A. W., & Daniel, M., (2018). Gender-specific associations between perceived and objective neighbourhood crime and metabolic syndrome. *PLoS One, 13*(7). https://doi.org/10.1371/journal.pone.0201336

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology, 51(6)*, 1173-1182. https://doi.org/10.1037/0022-3514.51.6.1173

Bogar, S., & Beyer, K. M. (2015). Green Space, Violence, and Crime: A Systematic Review. *Trauma, Violence, & Abuse, 17*(2), 1-12. https://doi.org/10.1177/1524838015576412

Branas, C., South, E., Kondo, M., Hohl, B., Bourgois, P., Wiebe, D., & MacDonald, J. (2018). Citywide cluster randomized trial to restore blighted vacant land and its effects on violence, crime, and fear. *Proceedings of the National Academy of Sciences of the United States of America, 115*(12), 2946-2951. https://doi.org/10.1073/pnas.1718503115

Campagnaro, T., Vecchiato, D., Arnberger, A., Celegato, R., Da Re, R., Rizzetto, R., Semenzato, P., Sitzia, T., Tempesta, T., & Cattaneo, D. (2020). General, stress relief and perceived safety preferences for green spaces in the historic city of Padua (Italy). *Urban Forestry and Urban Greening, 52*. https://doi.org/10.1016/j.ufug.2020.126695

Chan, Y. L. (2015). *Correlation between crime and vegetation: a case study of Jefferson*

*County, Kentucky* [College of Arts & Sciences Senior Honors Theses]. University of Louisville, Kentucky, United States.

Chen, B., Adimo, O. A., & Bao, Z. (2009). Assessment of aesthetic quality and multiple functions of urban green space from the users' perspective: The case of Hangzhou Flower Garden, China. *Landscape and Urban Planning, 93*(1), 76-82. https://doi.org/10.1016/j.landurbplan.2009.06.001

Cohen, L. E., & Felson, M. (1979). Social change and crime rate trends: a routine activity approach. *American Sociological Revie, 44(4)*, 588–608. https://doi.org/10.2307/2094589

Cumming (2013). The New Statistics: Why and How. *Association for Psychological Science, 25*(1), 7-29. https://doi.org/10.1177/0956797613504966

Daneshnejad, A., & Matin, M. (2015). The impact of urban green spaces create a sense of security and promoting mental health in the community. *Urban Management, 15*(42). 175-184.

Van Rompay, T. J. L., De Vries, P. W., & Damink, M. T. (2015). "For your safety": Effects of camera surveillance on safety impressions, situation construal and attributed intent. In T. MacTavish & S. Basapur (Eds.), *Persuasive Technology* (pp. 141-146). Springer, Cham. https://doi.org/10.1007/978-3-319-20306-5_13

Donovan, G. H., & Prestemon, J. P. (2012). The effect of trees on crime in Portland, Oregon. *Environment and Behavior, 44*(1), 3–30. https://doi.org/10.1177/0013916510383238

Dupuis, M., Baggio, S., & Gmel, G. (2015). Validation of a brief form of the Perceived Neighborhood Social Cohesion questionnaire. *Journal of Health Psychology, 22*(2), 218-227. https://doi.org/10.1177/1359105315600234

Dzhambov, A. M. (2014). Perceived Benefits of Nature Questionnaire: Preliminary Results. *Ecopsychology, 6*(2). http://doi.org/10.1089/eco.2013.0108

Ferraro, K. F. (1995). *Fear of crime: Interpreting victimization risk*. SUNY Press.

Ferraro, K. F., & LaGrange, R. L. (1992). Are older people most afraid of crime? Reconsidering age differences in fear of victimization. *Journal of Gerontology, 47*(5), 233-244. https://doi.org/10.1093/geronj/47.5.S233

Fisher, B. S., & Nasar, J. L. (1992). Fear of Crime in Relation to Three Exterior Site Features: Prospect, Refuge, and Escape. *Environment and Behavior, 24*(1), 35-65. https://doi.org/10.1177/0013916592241002

Gabriel, U., & Greve, W. (2003). The Psychology of Fear of Crime. Conceptual and

Methodological Perspectives. *British Journal of Criminology, 43*(3), 600-614. https://doi.org/10.1093/bjc/azg600

Garvin, E., Cannuscio, C, & Branas, C. (2013). Greening vacant lots to reduce violent crime: A randomised controlled trial. Injury Prevention, 19(3), 198-203. http://dx.doi.org/10.1136/injuryprev-2012-040439

Ghani, I., Rahman, N. A., Nayan, N. M., & Bahaluddin, A. (2018). Experiential Virtual Urban Environments: A Preliminary Investigation. *Planning Malaysia, 16*(1), 25-37.

Green, G., Gilbertson, J., & Grimsley, M. (2002). Fear of crime and health in residential tower blocks. A case study in Liverpool, UK. *European journal of public health, 12*(1), 10-5. https://doi.org/10.1093/eurpub/12.1.10

Greenberg, S.W., & Rohe, W.M. (1984). Neighbourhood Design and Crime. *Journal of the American Planning Association, 50*(1), 48-61. https://doi.org/10.1080/01944368408976581

Hackman, D. A., Robert, S. A., Grübel, J., Weibel, R. P., Anangnostou, E., Hölscher, J., & Schinazi, V. R. (2019). Neighborhood environments influence emotion and physiological reactivity. *Scientific Reports, 9*. https://doi.org/10.1038/s41598-019-45876-8

Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). New York, NY: Guilford Publications.

Hazra, A. (2017). Using the confidence interval confidently. *Journal of Thoracic Disease, 9*(10), 4125-4130. doi:10.21037/jtd.2017.09.14

Hinkle, J. (2015). Emotional Fear of Crime vs. Perceived Safety and Risk: Implications for Measuring "Fear" and Testing the Broken Windows Theory. *American Journal of Criminal Justice, 40*(1), 147-168. https://doi.org/10.1007/s12103-014-9243-9

Jamei, E., Mortimer, M., Seyedmahmoudian, M., Horan, B., & Stojcevski, A. (2017). Investigating the Role of Virtual Reality in Planning for Sustainable Smart Cities. *Sustainability, 9*(11). https://doi.org/10.3390/su9112006

Jennings, V., & Bamkole, O. (2019). The Relationship between Social Cohesion and Urban Green Space: An Avenue for Health Promotion. *International Journal of Environmental Research and Public Health, 16(3)*, 452. https://doi.org/10.3390/ijerph16030452

Jiang, B., Chang, C. Y., & Sullivan, W. C. (2014). A dose of nature: Tree cover, stress

reduction, and gender differences. *Landscape and Urban Planning, 132*, 26-36. http://dx.doi.org/10.1016/j.landurbplan.2014.08.005

Jiang, B., Mak, C., Larsen, L., & Zhong, H. (2017). Minimizing the gender difference in perceived safety: Comparing the effects of urban back alley interventions. *Journal of Environmental Psychology, 51*, 117-131. https://doi.org/10.1016/j.jenvp.2017.03.012

Jorgensen, A., Hitchmough, J., & Calvert, T. (2002). Woodland spaces and edges: Their impact on perception of safety and preference. *Landscape and Urban Planning, 60*(3), 135-150.

Kaplan, R., & Kaplan, S. (1989). The Experience of Nature: A Psychological Perspective. Cambridge: Cambridge University Press.

Karakus, O., McGarrell, E., & Basibuyuk, O. (2010). Fear of crime among citizens of Turkey. *Journal of Criminal Justice, 38*(2), 174-184. https://doi.org/10.11144/Javeriana.upsy17-3.fcce

Keil, T., & Vito, G. (1991). Fear of crime and attitudes toward capital punishment: a structural equation model. *Justice Quarterly, 8*, 447-464. https://doi.org/10.1080/07418829100091161

Kimpton, A., Corcoran, J., & Wickes, R. (2016). Greenspace and Crime: An Analysis of Greenspace Types, Neighboring Composition, and the Temporal Dimensions of Crime. *Journal of Research in Crime and Delinquency, 54*(3), 303-337. https://doi.org/10.1177/0022427816666309

Kondo, M. C., Han, S., Donovan, G. H., & MacDonald, J. M. (2017). The association between urban trees and crime: Evidence from the spread of the emerald ash borer in Cincinnati. *Landscape and Urban Planning, 157*, 193-199. https://doi.org/10.1016/j.landurbplan.2016.07.003

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine, 15*(2), 155-163. https://doi.org/10.1016/j.jcm.2016.02.012

Koskela, H., & Pain, R. (2000). Revisiting fear and place: women's fear of attack and the built environment. *Geoforum, 31*(2), 269-280. Retrieved on December 14, 2019, from https://doi.org/10.1016/S0016-7185(99)00033-0

Kuo, F. E., & Sullivan, W.C. (2001a). Environment and Crime in the Inner City: Does Vegetation Reduce Crime? *Environment and Behavior, 33*(3), 343-367. https://doi.org/10.1177/0013916501333002

Kuo, F.E., & Sullivan, W. C. (2001b). Aggression And Violence in the Inner City: Effects of

Environment via Mental Fatigue. *Environment and Behavior, 33*(4), 543-571. https://doi.org/10.1177/00139160121973124

Lee, J. S., Park, S., & Jung, S. (2016). Effect of Crime Prevention through Environmental Design (CPTED) Measures on Active Living and Fear of Crime. *Sustainability, 8*(9), 872. https://doi.org/10.3390/su8090872

Lis, A., Pardela, L., Can, W., Katlapa, A., & Rąbalski, Ł. (2019). Perceived Danger and Landscape Preferences of Walking Paths with Trees and Shrubs by Women. *Sustainability, 11*(17), 4565. https://doi.org/10.3390/su11174565

Luo, P., Miao, Y., & Zhao, J. (2020). Effects of auditory-visual combinations on students' perceived safety of urban green spaces during the evening. *Urban Forestry and Urban Greening.* https://doi.org/10.1016/j.ufug.2020.126904

Mouratidis, K. (2019). The impact of urban tree cover on perceived safety. *Urban Forestry and Urban Greening, 44.* https://doi.org/10.1016/j.ufug.2019.126434

Nasar, J. L., & Fisher, B. S. (1993). Hot spots of fear and crime: A multi-method investigation. *Journal of Environmental Psychology, 13(3)*, 187–206. https://doi.org/10.1016/S0272-4944(05)80173-2

Nasar, J. L., & Jones, K. M. (1997). Landscapes of Fear and Stress. *Environment and Behavior, 29*(3), 291-323. https://doi.org/10.1177/001391659702900301

Okunola, S., & Amole, D. (2012). Perceptions of Safety, Social Participation and Vulnerability in an Urban Neighbourhood, Lagos, Nigería. Social and Behavioral Sciences, 35, 505-513. https://doi.org/10.1016/j.sbspro.2012.02.116

Ozbil, A., Argin, G., & Yesiltepe, D. (2016). Pedestrian route choice by elementary school students: the role of street network configuration and pedestrian quality attributes in walking to school. *International Journal of Design Creativity and Innovation, 4*(2), 67-84. https://doi.org/10.1080/21650349.2015.1123120

Pánek, J., Ivan, I., & Macková, L. (2019). Comparing Residents' Fear of Crime with Recorded Crime Data—Case Study of Ostrava, Czech Republic. *International Journal of Geo-Information, 8*(9), 401. https://doi.org/10.3390/ijgi8090401

Piga, B., & Morello, E. (2015). Environmental design studies on perception and simulation: an urban design approach. *Ambiences, 1.* https://doi.org/10.4000/ambiances.647

Rezvanipour, S., Hassan, N., Ghaffarianhoseini, A., & Danaee, M. (2021). Why does the perception of street matter? A dimensional analysis of multisensory social and physical attributes shaping the perception of streets. *Architectural Science Review.* https://doi.org/10.1080/00038628.2020.1867818

Sampson, R. J. (2012). *Great American City: Chicago and the Enduring Neighborhood Effect.* The University of Chicago Press, London, New York.

Saville, G., & Cleveland, G. (2003a). An Introduction to 2nd Generation CPTED: Part 1. *CPTED Perspectives, 6*(2), 4-8.

Saville, G., & Cleveland, G. (2003b). An Introduction to 2nd Generation CPTED: Part 1. *CPTED Perspectives, 6*(1), 7-9.

Saville, G., & Cleveland, G. (2008). Second-Generation CPTED: The Rise and Fall of Opportunity Theory. In R. I. Atlas (Eds.), *21st Century Security and CPTED: Designing for Critical Infrastructure, Protection and Crime Preventio (pp. 79-91).* CRC Press Taylor & Francis Group.

Slater, M., Sanchez-Vives, M. V. (2014). Transcending the Self in Immersive Virtual Reality. *Institute of Electrical and Electronics Engineers, 47* (7). https://doi.org/10.1109/MC.2014.198

Stamps, A. E. (2013). Effects of Multiple Boundaries on Perceived Spaciousness and Enclosure. *Environment and Behavior, 45*, 851–875. https://doi.org/10.1177/0013916512446808

Tabrizian, P., Baran, P. K., Smith, W. R., & Meentemeyer, R. K. (2018). Exploring perceived restoration potential of urban green enclosure through immersive virtual environments. *Journal of Environmental Psychology, 55*, 99-109. https://doi.org/10.1016/j.jenvp.2018.01.001

Talbot, J., & Kaplan, R. (1984). Needs and fears: The response to trees and nature in the inner city. *Journal of Arboriculture*, *10*(8), 222-228.

Taub, R., Taylor, D. G., & Dunham, J. D. (1981). Neighbourhood and safety. In D. A. Lewis (Ed.), *Reactions to crime* (pp. 299-354). Newbury Park, CA: Sage.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. http://creativecommons.org/licenses/by/3.0

Ulrich, R. S. (1986). Human Responses to Vegetation and Landscapes. *Landscapes and Urban Planning, 13*, 29-44. https://doi.org/10.1016/0169-2046(86)90005-8

Ulrich, R. W. (1984). View through a window may influence recovery from surgery. *Science, 224*(4647), 420–421. doi:10.1126/science.6143402

Ulrich, R.S., Simons, R., Losito, B., Fiorito, E., Miles, M., & Zelson, M. (1991). Stress

Recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*(3), 201-230. https://doi.org/10.1016/S0272-4944(05)80184-7

Unity Technologies (2020). Unity (Version 2019.3.10) [Computer Software]. Retrieved on March 21, 2020 from https://unity.com/releases/2019-3

Van den Bogerd, N., Dijkstra, S. C., Seidell, J. C., & Maas, J. (2018). Greenery in the university environment: Students' preferences and perceived restoration likelihood. *PLoS ONE,13*(2). https://doi.org/10.1371/journal.pone.0192429

Van Dongen, R. P., & Timmermans, H. J. P. (2019). Preference for different urban greenscape designs: A choice experiment using virtual environments. *Urban Forestry and Urban Greening, 44*. https://doi.org/10.1016/j.ufug.2019.126435

Van Gelder, J.-L., Hershfield, H. E., & Nordgren, L. (2013). Vividness of the future self reduces delinquency. *Psychological Science, 24*(6), 974-980. https://doi.org/10.1177/0956797612465197

Wolfe, M. K., & Mennis, J. (2012). Does vegetation encourage or suppress crime? Evidence from Philadelphia, PA. *Landscape and Urban Planning, 108*(2-4), 112-122. https://doi.org/10.1016/j.landurbplan.2012.08.006

Yeater, E. A., Treat, T. A., Viken, R. J., & McFall, R. M. (2010). Cognitive Processes Underlying Women's Risk Judgments: Associations With Sexual Victimization History and Rape Myth Acceptance. *Journal of Consulting and Clinical Psychology, 78*(3). 375-386. https://doi.org/10.1037/a0019297

Yong, A. G., & Pearce, S. (2013). A Beginner's Guide to Factor Analysis: Focusing on Exploratory Factor Analysis. *Tutorials in Quantitative Methods for Psychology, 9* (2), 79-94. doi:10.20982/tqmp.09.2.p079

## Appendix A

Full Questionnaire

[Confirmation informed consent]

Phase A – After first VR exposure in daylight

Question 1. Perceived safety – 5-point Likert scale: strongly disagree to strongly agree
Please indicate for each item to what extent you agree or disagree by choosing the answer that best reflects your opinion.

1. ‘‘In this neighborhood, people really do not need to lock their doors when they leave their homes for a short period of time’’
2. ‘‘People who live in this neighborhood have to worry about someone breaking into their home to steal things’’
3. ‘‘People in this neighborhood can walk around at night without fear of being attacked or bothered by strangers’’
4. ‘‘People in this neighborhood can leave their personal property outside and unattended without fearing that it will be damaged or stolen.’’

Question 2. Perceived neighborhood social cohesion – assessed on 5-point Likert scale
Next we are interested in your perceptions of the neighborhood social resources. Based on the environment you have just experienced we would like you to imagine what kind of people live in this neighborhood and what relationships they have.

Please indicate to what extent you agree or disagree by choosing the answer that best reflects your opinion.

1. Most people in this area can be trusted.
2. People in this area will take advantage of you.
3. If you were in trouble, there are a lot of people who would help you.
4. Most people in this area are friendly.
5. People in this area have lots of community spirit.
6. People in this area do things to help the community.
7. People in this area treat each other with respect.
8. People in this area are tolerant of others who are not like them.

9. In this area there are people who belong and some who don't.

Phase B – After second VR exposure by night

Question 3. Perceived safety – 5-point Likert scale: strongly disagree to strongly agree
Please indicate for each item to what extent you agree or disagree by choosing the answer that best reflects your opinion.

1. ''In this neighborhood, people really do not need to lock their doors when they leave their homes for a short period of time''
2. ''People who live in this neighborhood have to worry about someone breaking into their home to steal things''
3. ''People in this neighborhood can walk around at night without fear of being attacked or bothered by strangers''
4. ''People in this neighborhood can leave their personal property outside and unattended without fearing that it will be damaged or stolen.''

Question 4. Perceived neighborhood social cohesion – assessed on 5-point Likert scale
For the next nine items we kindly like to ask you to indicate again to what extent you agree or disagree by choosing the answer that best reflects your opinion.

1. Most people in this area can be trusted.
2. People in this area will take advantage of you.
3. If you were in trouble, there are a lot of people who would help you.
4. Most people in this area are friendly.
5. People in this area have lots of community spirit.
6. People in this area do things to help the community.
7. People in this area treat each other with respect.
8. People in this area are tolerant of others who are not like them.
9. In this area there are people who belong and some who don't.

Question 5. Interpretation of ambiguous situation
We would now like to ask you to take a moment and think back to the second part of the experiment. In this part you have experienced the environment by night. We would like you to think back to the moment where you had to decide which way to choose when you reached the junction at the end of the road. If you remember there were three young men standing opposite of you and slightly on the left side in the park. We are interested in your opinion

about what you think these three men were doing in the park in the middle of the night. Please take a moment and write a short story-board of at least 3 (or more) sentences about what you believe has happened there. You can think of questions like "Do you think these three men knew each other?", "What were they doing in the middle of the night out in the park?", "Would you have approached them if you needed to ask e.g. for directions?", "Which way did you choose to go and why?" etc...

Please be creative and elaborate on your answer. There is no right or wrong answer, we are simply interested in your perceptions/interpretations of this situation and the decisions you make.

Question 6. Dispositional fear of crime_A

At one time or another, most of us have experienced fear about becoming a victim of crime. Some crimes probably frighten you more than others. We are interested in how afraid people are in everyday life of being a victim of different kinds of crimes. Please rate your fear on a scale from 1 to 5 where 1 means you are "not afraid at all" and 5 means you are "very afraid". Please, rate your fear of ...

1. Being approached on the street by a beggar or panhandler (homeless person).
2. Being cheated, conned, or swindled out of your money.
3. Having someone break into your home while you are away.
4. Having someone break into your home while you are there.
5. Being raped or sexually assaulted.
6. Being murdered.
7. Being attacked by someone with a weapon.
8. Having your car stolen.
9. Being robbed or mugged on the street.
10. Having your property damaged by vandals.

Question 7. Dispositional fear of crime_B – 5-point Likert scale

Again, please rate the following 6 items on a scale from 1 to 5, where 1 means not at all and 5 means you find it very likely, or you do that very often.

1. “How often are you afraid of becoming a victim of physical assault?”
2. “How often are you afraid of becoming a victim of a crime outside your apartment?”

3. “How likely do you think it is that you will become a victim of physical assault (during the next twelve months)?”
4. “How likely do you think it is that you will become a victim of crime outside (during the next twelve months)?”
5. “Do you carry anything to defend yourself (against physical assault)?
6. “Do you avoid public transport when out at night?”

Question 8. Perceived benefits of nature – 5-point Likert scale: Very uncharacteristic of me – very characteristic of me

In the following, we ask you to make statements concerning perceived benefits of nature. "Nature" in this context only refers to vegetation, like urban nature and wilderness. "Interaction" refers to both direct contact (i.e. being surrounded by nature) and indirect visual contact with natural scenes. Please answer spontaneously without much thinking. Please answer whether you can generally accept the statement or not. We are interested in your individual view. Accordingly, there exist no right or wrong answers. If you feel uncertain which of the rating categories apply, please choose the rating category which best fits with your personal view.

1. Interacting with nature makes me happy.
2. Interacting with nature keeps me optimistic.
3. Not interacting with nature poorly affects my physical health.
4. Visualizing natural scenes makes me happy.
5. In order to maintain physical health, I have to interact with nature.
6. I am more positive when I think of nature.
7. I feel relaxed when I think of nature.
8. In order not to feel anxious, I have to interact with nature.
9. I feel uneasy when I am apart from nature for a long time.
10. I am more capable of gathering my thoughts on the things I need to do when I am close to nature.
11. Not interacting with nature affects my ability to easily cope with unpleasant thoughts.

Question 9. Previous victimization

1. ‘‘Have you or anyone close to you ever had their home broken into and/or had something stolen?’’

2. ‘‘Have you or anyone close to you ever been attacked, mugged, or robbed while out walking?”

Question 10.
Please indicate your age in years.

Question 11.
Please indicate your nationality.
Dutch
German
Other, namely...

Question 12.
To which gender identity do you most identify?
Male
Female
Other, namely …

Question 13.
Please indicate your current occupation.
Employed full-time
Employed half-time
Unemployed
Retired
Student
Other, namely ...

Question 14.
Are you participating in this study by using SONA-system (a platform for students of the UT)?

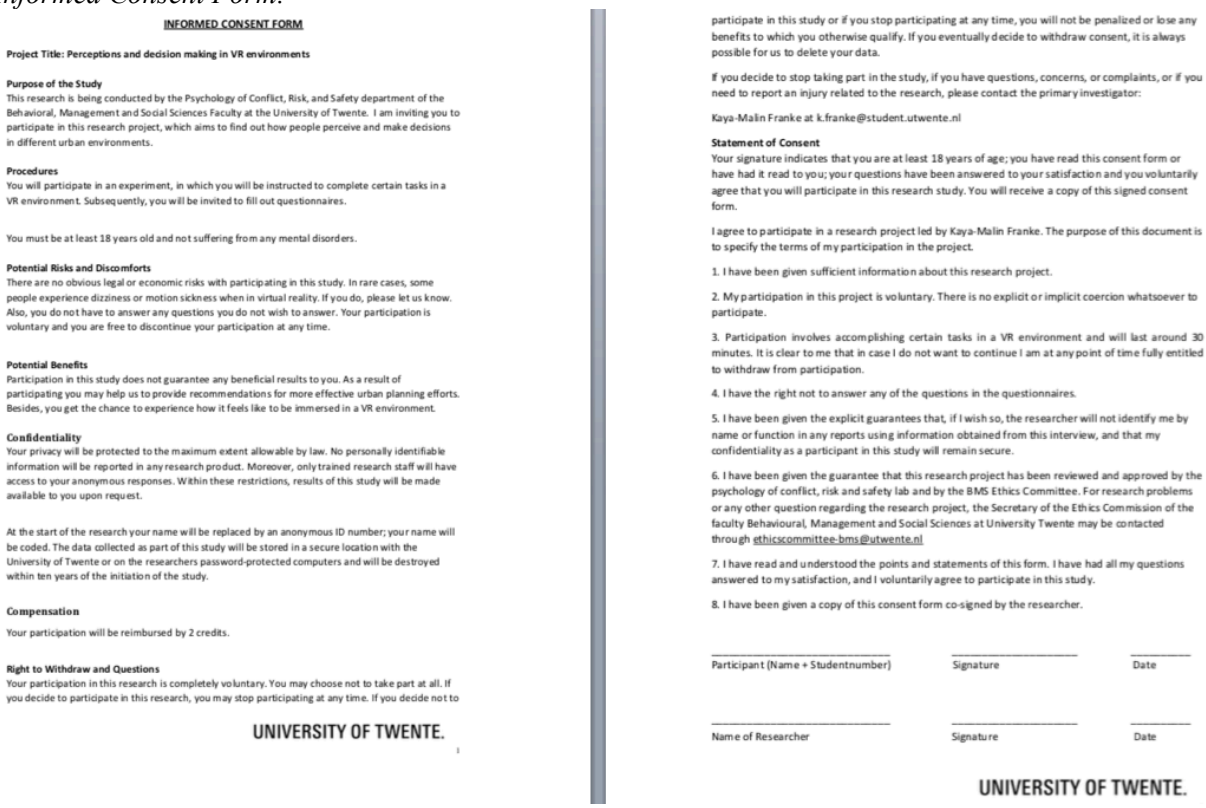
Question 15.
What is your student number? (If you don’t have one, please ask the researcher for an ID)

# Appendix B

Informed Consent Form and Viral Infection Checklists

**Figure B1**

*Informed Consent Form.*



**INFORMED CONSENT FORM**

**Project Title: Perceptions and decision making in VR environments**

**Purpose of the Study**
This research is being conducted by the Psychology of Conflict, Risk, and Safety department of the Behavioral, Management and Social Sciences Faculty at the University of Twente. I am inviting you to participate in this research project, which aims to find out how people perceive and make decisions in different urban environments.

**Procedures**
You will participate in an experiment, in which you will be instructed to complete certain tasks in a VR environment. Subsequently, you will be invited to fill out questionnaires.

You must be at least 18 years old and not suffering from any mental disorders.

**Potential Risks and Discomforts**
There are no obvious legal or economic risks with participating in this study. In rare cases, some people experience dizziness or motion sickness when in virtual reality. If you do, please let us know. Also, you do not have to answer any questions you do not wish to answer. Your participation is voluntary and you are free to discontinue your participation at any time.

**Potential Benefits**
Participation in this study does not guarantee any beneficial results to you. As a result of participating you may help us to provide recommendations for more effective urban planning efforts. Besides, you get the chance to experience how it feels like to be immersed in a VR environment.

**Confidentiality**
Your privacy will be protected to the maximum extent allowable by law. No personally identifiable information will be reported in any research product. Moreover, only trained research staff will have access to your anonymous responses. Within these restrictions, results of this study will be made available to you upon request.

At the start of the research your name will be replaced by an anonymous ID number; your name will be coded. The data collected as part of this study will be stored in a secure location with the University of Twente or on the researchers password-protected computers and will be destroyed within ten years of the initiation of the study.

**Compensation**
Your participation will be reimbursed by 2 credits.

**Right to Withdraw and Questions**
Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify. If you eventually decide to withdraw consent, it is always possible for us to delete your data.

If you decide to stop taking part in the study, if you have questions, concerns, or complaints, or if you need to report an injury related to the research, please contact the primary investigator:

Kaya-Malin Franke at k.franke@student.utwente.nl

**Statement of Consent**
Your signature indicates that you are at least 18 years of age; you have read this consent form or have had it read to you; your questions have been answered to your satisfaction and you voluntarily agree that you will participate in this research study. You will receive a copy of this signed consent form.

I agree to participate in a research project led by Kaya-Malin Franke. The purpose of this document is to specify the terms of my participation in the project.

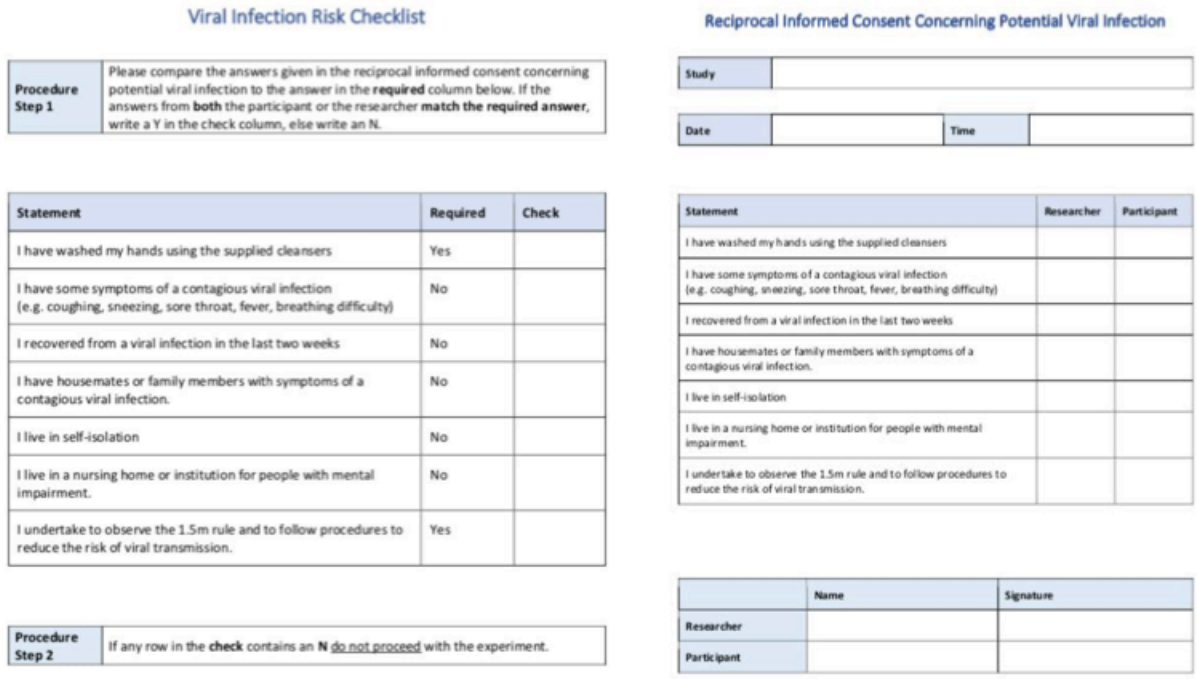
1. I have been given sufficient information about this research project.
2. My participation in this project is voluntary. There is no explicit or implicit coercion whatsoever to participate.
3. Participation involves accomplishing certain tasks in a VR environment and will last around 30 minutes. It is clear to me that in case I do not want to continue I am at any point of time fully entitled to withdraw from participation.
4. I have the right not to answer any of the questions in the questionnaires.
5. I have been given the explicit guarantees that, if I wish so, the researcher will not identify me by name or function in any reports using information obtained from this interview, and that my confidentiality as a participant in this study will remain secure.
6. I have been given the guarantee that this research project has been reviewed and approved by the psychology of conflict, risk and safety lab and by the BMS Ethics Committee. For research problems or any other question regarding the research project, the Secretary of the Ethics Commission of the faculty Behavioural, Management and Social Sciences at University Twente may be contacted through ethicscommittee-bms@utwente.nl
7. I have read and understood the points and statements of this form. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.
8. I have been given a copy of this consent form co-signed by the researcher.

| Participant (Name + Studentnumber) | Signature | Date |
|---|---|---|
| Name of Researcher | Signature | Date |

UNIVERSITY OF TWENTE.

**Figure B2**

*Viral Infection Checklists.*



**Viral Infection Risk Checklist**

| | |
|---|---|
| **Procedure Step 1** | Please compare the answers given in the reciprocal informed consent concerning potential viral infection to the answer in the **required** column below. If the answers from **both** the participant or the researcher **match the required answer**, write a Y in the check column, else write an N. |

| Statement | Required | Check |
|---|---|---|
| I have washed my hands using the supplied cleansers | Yes | |
| I have some symptoms of a contagious viral infection (e.g. coughing, sneezing, sore throat, fever, breathing difficulty) | No | |
| I recovered from a viral infection in the last two weeks | No | |
| I have housemates or family members with symptoms of a contagious viral infection. | No | |
| I live in self-isolation | No | |
| I live in a nursing home or institution for people with mental impairment. | No | |
| I undertake to observe the 1.5m rule and to follow procedures to reduce the risk of viral transmission. | Yes | |

| | |
|---|---|
| **Procedure Step 2** | If any row in the **check** contains an **N** do not proceed with the experiment. |

**Reciprocal Informed Consent Concerning Potential Viral Infection**

| | | | |
|---|---|---|---|
| **Study** | | | |
| **Date** | | **Time** | |

| Statement | Researcher | Participant |
|---|---|---|
| I have washed my hands using the supplied cleansers | | |
| I have some symptoms of a contagious viral infection (e.g. coughing, sneezing, sore throat, fever, breathing difficulty) | | |
| I recovered from a viral infection in the last two weeks | | |
| I have housemates or family members with symptoms of a contagious viral infection. | | |
| I live in self-isolation | | |
| I live in a nursing home or institution for people with mental impairment. | | |
| I undertake to observe the 1.5m rule and to follow procedures to reduce the risk of viral transmission. | | |

| | Name | Signature |
|---|---|---|
| **Researcher** | | |
| **Participant** | | |

## Appendix C

Project Documentation: Developed in the BMS LAB

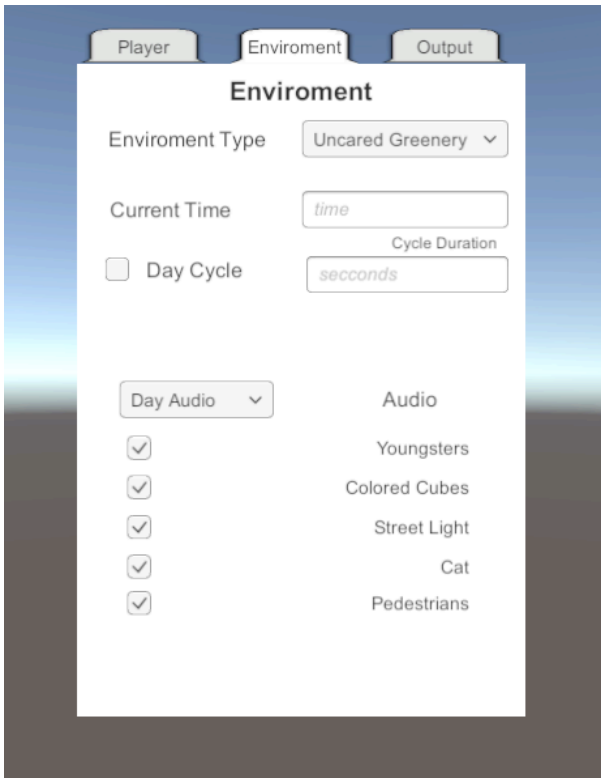
**Table of Contents**

## 1. General Overview

### a. Project Overview

This is a research tool that allows the researchers to conduct experiments with different urban environments. There are three environments that the researchers can choose from, either an environment with well-maintained urban green space, one with uncared urban green space or one with no urban green space at all. The researchers can adjust the scenes to suit their purposes by adding, removing, dragging, and moving green space or other objects (e.g. lanterns and benches) into the environments. They will also be able to record the time spend in the scenes.

This tool was developed as part of a research aimed at discovering whether differences in the presence and maintenance of urban green space cause differences in how safe people feel and how they interpret ambiguous situations. The idea is to compare people's perceptions and decision making in these three different environments by having them experience these environments in daylight and during nighttime and in between each exposure give ratings to several variables of interest. This might allow implications for crime prevention by providing recommendations for more effective urban planning efforts. The experiment will test if people have greater safety perceptions and interpret ambiguous situations more positively in environments featuring well-maintained urban green space compared to environments featuring uncared or no green space at all.




### b. Software/hardware

- Unity 2019.3.10
- Windows 10 Support

### c. GUI Elements

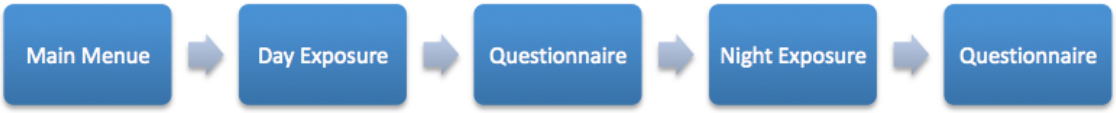
There is a main menu that allows researchers to choose between the different environments and to make other choices regarding what these environments should entail ahead of the experiment.

These include the time of the day, whether the environment should feature day or night sound effects, an ambiguous scene of three young men hanging around in a park, colored cubes which the participants should

search for around the city, street lights, a cat, and pedestrians. Besides the researcher can specify an identification number and set a move speed for each participant, as well as decide whether he/she wants to record the session. Afterwards the researcher will be able to launch the scene.

### d. Experiment Flow

The following is the experiment flow for each user

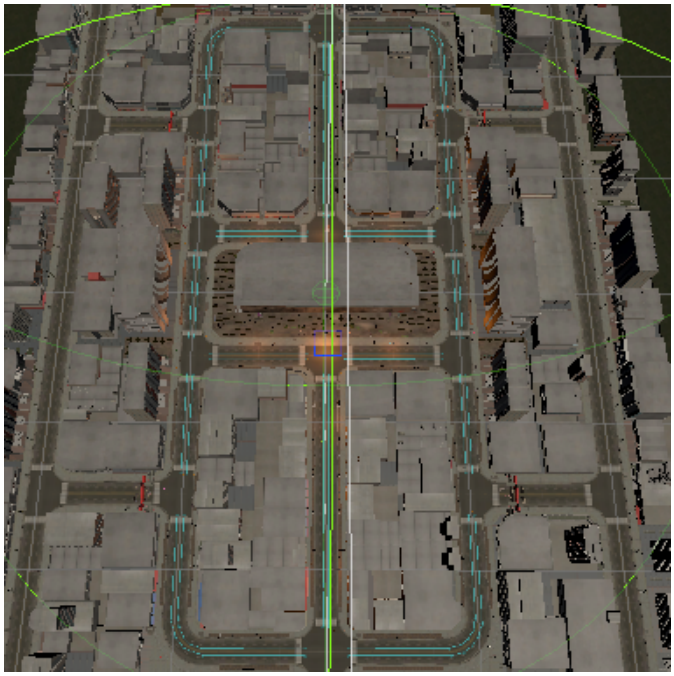



### e. Settings

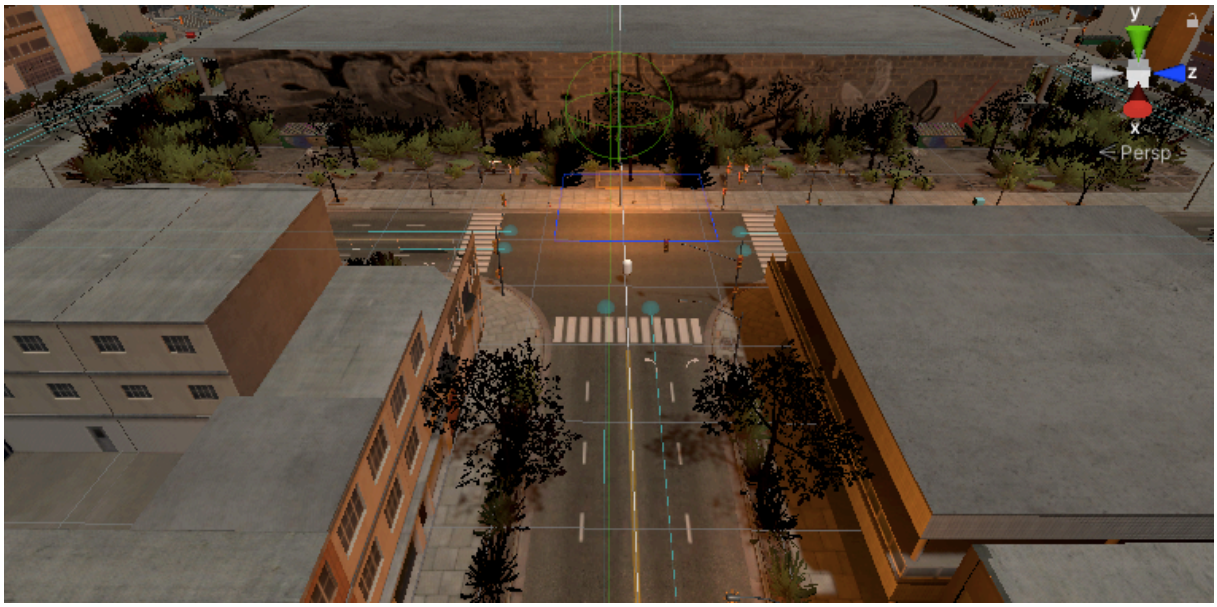
The project is equipped with three environments, for each environment the researcher can edit the scene. There are lots of customization options and buttons to click to customize the scene.

**f. Map**

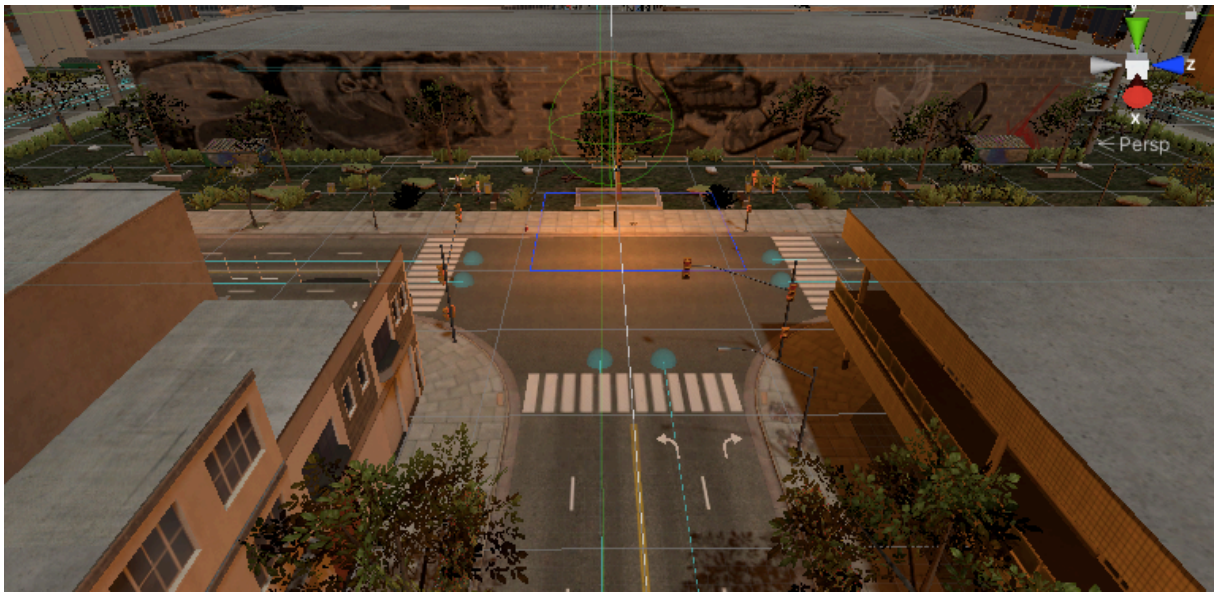
The following image displays how the three different environments look from a bird's- eye view.



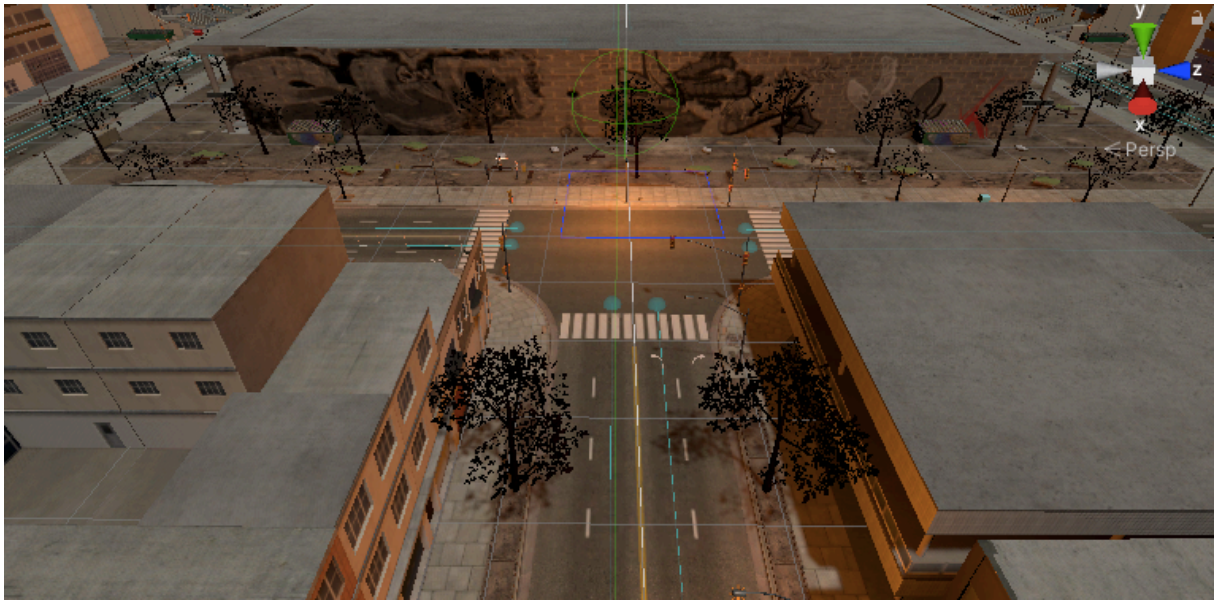
Next, a section of the environment will be displayed to give an impression of how the three environments differ.




*1. Urban environment with uncared green space*




*2. Urban environment with well-maintained green space*




*3. Urban environment without green space*

## g. User Interface for Customization


1. The user can specify an identification number for the participant.
2. The user can decide the move speed within the environment.
3. The user can choose between three different environments.
    - Well-maintained greenery
    - Uncared greenery
    - No greenery
4. The user can change the time of the day by typing a number between 0 to 1 where 0 or 1 equal 24 pm and 0.5 equals noon.
    - During the day exposure the time was set to 0.6
    - During the night exposure the time was set to 0.1
5. The user can specify whether the environment should feature day or night audio effects.

6. By selecting or deselecting various boxes the user can decide what the environment should feature. Besides these functions the environment also featured fog during both day and night exposure.
    - After a couple of pilot tests it was decided to only select 'pedestrians' and to leave out the task of finding colored cubes around the city during the day exposure
    - During the night exposure only 'youngsters', and 'street light' were selected as the outcome of the pilot tests suggested to leave out the 'cat' as it distracted too much from the ambiguous situation and was looking too friendly
7. The user can decide to record the scene. This box was selected during the night exposure.
8. The user can press "launch scene" to start the experiment.

### *2. Technical Overview*

**a. Assets Used**

- **Meadow Environment – Dynamic Nature:** This assets used to make the two environments as well as the trees.
    - Asset: https://assetstore.unity.com/packages/3d/vegetation/meadow-environment- dynamic-nature-132195
- **NatCoder – Video Recording API:** This asset is used to record the scene after the user type the recording time. *Note: this assets currently have problems as the recording framerate and resolution is not great.*
    - Asset: https://assetstore.unity.com/packages/tools/integration/natcorder-video-recording-api-102645
- **VR Capture:** This asset record the screen as well. However, it displays the logo of the company, but since the other recording asset is still not great, the user can also record using this asset by clicking the button on the bottom left corner of the screen.
    - Asset: https://assetstore.unity.com/packages/tools/video/vr-capture-75654
- **AQUAS:** This asset is used to add and draw the rivers into the scene.
    - Asset: https://assetstore.unity.com/packages/tools/particles-effects/aquas-water- river- set-52103
- **Unity Samples: UI:** This asset is used to make the main menu scene. o https://assetstore.unity.com/packages/essentials/unity-samples-ui-25468
- **AllSky Free – 10 Sky / Skybox Set:** This asset is used for the sky's in the scene.

    - Asset: https://assetstore.unity.com/packages/2d/textures-materials/sky/allsky-free- 10-sky-skybox-set-146014
- **Wooden Park Chair:** This asset is used to add the benches into the scene
    - Asset: https://assetstore.unity.com/packages/3d/props/exterior/wooden-park-chair- 851
- **Wall: Graffiti Urban – Graffiti Wall Asset:** This asset is used to create the impression of an urban environment that is rather run-down and not too wealthy. The graffiti walls that are currently used in the environment can be changed by dragging & dropping other graffiti wall prefabs into the scene.
    - Asset: https://assetstore.unity.com/packages/3d/environments/urban/wall-graffiti-urban-24750
- **CC_Assets – Pedestrian Asset:** This asset is used to create characters, which currently function as pedestrians during the daylight exposure and are placed at different spots all around the city. There are two characters available called 'Guy4' and 'Guy5', which were duplicated to achieve a total amount of 10 pedestrians. To make them look slightly different, so that it will be less obvious that they are all clones of two prefab characters, their cloth and their hair color was changed. This can be achieved by duplicating the desired material and then changing the main color of this material/texture in the inspector. To duplicate a material one either right-clicks the material in the project view and selects 'reveal in finder' where this material can then be duplicated or by using the short-cut Ctrl/Cmd + D (on Windows and Mac). Furthermore, it is possible to change the current animation of these pedestrians by making use of the programme 'iClone'.
    - iClone7: https://www.reallusion.com/iclone/
- **Audio files:** To achieve a more realistic VR experience the urban environments are equipped with different audio effects. For the daylight exposure an audio clip featuring suburban ambience with English voices is used. For the nighttime exposure it is made use of more than one audio clip, including one that features soft wind, one with the sound of a distant barking dog, and one that features murmuring and talking men. These audio clips can be enabled, disabled or changed into any audio clip that is preferred by adding new audio clips to the project. Example websites that provide free and downloadable audio sound effects are the following:
    - https://www.epidemicsound.com
    - https://www.youtube.com/audiolibrary/soundeffects?nv=1

- **Colored cubes:** To give the participants a task in the first phase of the experiment in which they experience the VR environment by daylight, 14 differently colored cubes are placed at random spots all around the city. These cubes can be enabled, disabled or adjusted to fit one's purposes. It is possible to change the color of a cube by selecting the cube and changing its main color in the inspector. It is also possible to create more cubes by duplicating them.

**b. Scenes**

- Main Menu
- No Greenery
- Uncared Greenery
- Well-maintained Greenery

Location: Assets/scripts

**c. Scripts Developed and their Locations in the Project**

- **AudioZone.cs :** Used as a Collider on trigger listener to toggle the Characters Audio ON/OFF
    - Object Attached: Characters -> Trees -> Audio Zone(Talking)
- **CanvasControls.cs**: Used to allow the user to Pause within a scene quit or go back to main Menu
    - Object Attached: Pause.
- **CharacterCameraController.cs:** Used to allow the user to Move the viewport on camera with mouse.
    - Object Attached: FPS.
- **CharacterMovementController.cs**: Allow the user to move the FPS object around using W,A,S,D Keys.
    - Object attached: FPS.
- **DayNight.cs**: Controls what time of the day and toggling between days cycling ability.
    - Object attached: Sun.
- **output.cs** : this script is made of two classes, Output Class and CsvReadWrite Class. this script is to record which direction the user chooses to go and how long for them to take a decision.

    - Object attached: FPSCamera.
    - Object attached: CVirtPlayerController.
- **sceneManager1.cs:** the primary role of this script is to gather all required information from the main menu and initialize the required scene with the user defined options.
    - Object attached: SceneManager.
- **Light Flicker Effect:** To further manipulate a person's perception of safety during the night exposure in the urban environment it is made use of a light flicker effect, which adds a somewhat scary effect. How to add this light flicker effect to a streetlight is clearly explained in the following Youtube tutorial:
    - https://www.youtube.com/watch?v=J_E7cmb2Or0.

  A publicly available C#script (code) for the light flicker effect can be found in the comment section of this video. The tutorial explains how to copy and paste this code into unity.
- **Player Walking Sound:** A C#script called 'Footsteps' that adds a walking sound to the player can be found under 'scripts' in the project view. This sound effect can be enabled, disabled or adjusted to fit one's purposes. The following Youtube tutorial explains how to create random footstep sounds with an audioclip and a C#script:
    - https://www.youtube.com/watch?v=ih8gyGeC7xs
    - 'Walk on Concrete' sound effect: https://www.youtube.com/audiolibrary/soundeffects?nv=1

Location of the scripts: Assets/Scripts.

### *3. Research Video*

**a. Insight Into the Purpose & Design of the Study**

- Link: https://www.youtube.com/watch?v=-_BpSOgZB_Q

## Appendix D

Detailed Account of the Exploratory Section

Results did not change notably**,** when analyzing the moderation effect in H1 using adjusted scales (including merging the two fear of crime measurements). As can be inferred from the wide CIs and the small point estimates in Table D1 it is unlikely that fear of crime had any moderating influence in how safe participants felt depending on their group allocation.

**Table D1**

*Confidence Intervals for Moderation Analyses of Fear of Crime Measurements (M), UGS (IV), and Perceived Safety at Night (DV)*

| | | *95% Confidence Interval for b* | |
|---|---|---|---|
| [a]Variable interaction | *b* | *Lower Bound* | *Upper Bound* |
| [b]X1 x Fear of Crime_AB | .09 | -.56 | .75 |
| [b]X2 x Fear of Crime_AB | -.25 | -.91 | .41 |

*Note.* [a]X1 and X2 correspond to the uncared UGS and the well-maintained UGS group respectively and the control group is the reference group. [b]Without interaction: $R^2$ = .03, $F(5, 72)$ = .47; Interaction: $\Delta R^2$ = .01, $\Delta F(2, 72)$ = .46.

When rerunning the mediation analyses with an adjusted scale for perceived safety there were no notable differences observed. Table D2 does not provide evidence for a direct effect of well-maintained UGS when the mediator was added to the model or a total effect (without the mediator) on the interpretation of ambiguous situation. Furthermore, the BCa bootstrap CI included zero, indicating the absence of an indirect effect. Perceived safety did not act as a mediator between well-maintained UGS and interpretations of the ambiguous situation, a*b = -.05, 95% *BCa CI* [-.21, .11]. It cannot be predicted that the true effect size is different from no effect as the CI contains zero in the proximity of its center, $b^2$ = -.07, 95% *BCa CI* [-.28, .15].

**Table D2**

*Steps of the Mediation Analysis of Perceived Safety on the Relationship Between Well-Maintained UGS and Interpretation of Ambiguous Situation*

| | | | | | | *95% Confidence Interval* | |
|---|---|---|---|---|---|---|---|
| | $R^2$ | *F* | *b* | *SE* | *t* | *LLCI* | *ULCI* |
| a-path | .01 | .31 | | | | | |
| D1 | | | .01 | .21 | .07 | -.39 | .42 |
| D2 | | | -.13 | .21 | -.65 | -.54 | .28 |
| b-path | .16 | 4.70 | | | | | |
| Perceived Safety | | | .41* | .11 | 3.67 | .19 | .64 |
| c-path | .00 | .28 | | | | | |
| D1 | | | .10 | .21 | .46 | -.33 | .52 |
| D2 | | | -.06 | .21 | -.29 | -.49 | .37 |
| Direct (c'-path) | .16 | 4.70 | | | | | |
| D1 | | | .09 | .20 | .47 | -.30 | .49 |
| D2 | | | -.01 | .20 | -.03 | -.40 | .39 |
| Indirect (a*b) | | | *b* | *BootSE* | | *BootLLCI* | *BootULCI* |
| D1 | | | .01 | .10 | | -.17 | .22 |
| D2 | | | -.05 | .08 | | -.21 | .11 |

*Note.* The UGS variable was dummy coded with uncared UGS (D1), well-maintained UGS (D2), and control as the reference group. $N = 76$.

The same holds for the analyses of the moderation effect in H3. Even though still not in the expected direction there was a moderation effect of perceived benefits of nature on the relationship between uncared UGS and interpretations of ambiguous situations. However, again only at lower levels of perceived benefits of nature. Furthermore, the lengthy CIs again speak for an uncertainty with regard to the precision of the estimates (see Table D3). Inferences about the size of the observed moderating effect and the amount of variance observed in the positivity of interpretations at low levels of the moderator must be made with caution.

**Table D3**

*Confidence Intervals for Moderation Analyses Perceived Benefits of Nature (M), UGS (IV), and Interpretation of Ambiguous Situation (DV)*

| | | *95% Confidence Interval for b* | |
|---|---|---|---|
| [a]Variable interaction | *b* | *Lower Bound* | *Upper Bound* |
| [b]X1 x Perceived Benefits of Nature | -.86 | -1.53 | -.19 |
| [b]X2 x Perceived Benefits of Nature | -.37 | -1.07 | .32 |

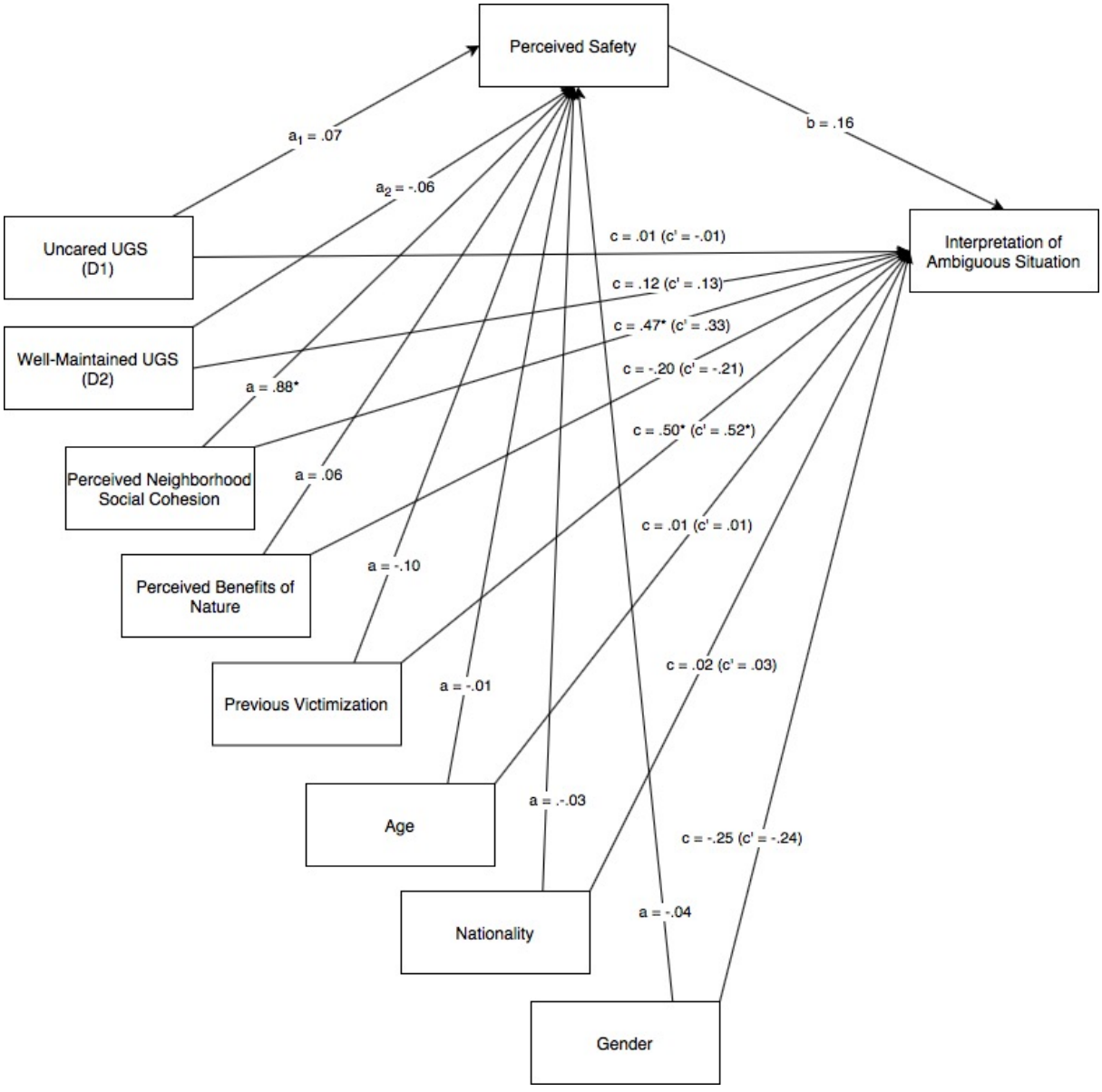
*Note.* [a]X1 and X2 correspond to the dummy coded uncared UGS and the well-maintained UGS group respectively and the control group is the reference group ($N = 76$). [b]Model without interaction term: $R^2 = .11$, $F(5, 70) = 1.68$; Interaction: $\Delta R^2 = .08$, $\Delta F(2, 70) = 3.29$.

To increase the accuracy of the previous analyses several potential covariates were taken into account, including age, gender, nationality, previous victimization and perceived neighborhood social cohesion and perceived benefits of nature. Furthermore, identified outliers were not taken into account. Nonetheless, results showed that the interaction term between fear of crime and the experiment groups did not lead to an added amount of variance in perceived safety (H1). Interestingly though, there was a notable main effect between perceived neighborhood social cohesion and perceived safety ($b$ = .88, $t(65)$ = 7.47) with a 95% *CI* [.65, 1.12] that is relatively far away from zero and narrow in width, indicating greater precision in predicting the true population effect. This adds trust in assuming that as perceived neighborhood social cohesion increases, perceived safety increases as well, and fits with the moderate positive correlation found between these variables (see Table 2, p. 19).

Adding the above listed covariates to the mediation model of H2 resulted in the following outcome (see Figure D1 for all path coefficients of the mediation model). While the UGS groups as compared to the control group did not predict the mediator perceived safety (path a), the covariate perceived neighborhood social cohesion did ($b$ = .88, 95% *CI* [.65,1.12], $t(68)$ = 7.65, $R^2$ = .55). Next, perceived safety did not predict one's interpretation of the ambiguous situation (path b) anymore with covariates included in the model. There was also no direct effect found of the two groups on the DV. Interestingly, with the mediator included in the model (path c') the covariate perceived neighborhood social cohesion did not predict the DV anymore, but previous victimization did ($b$ = .52, 95% *CI* [.19, .85], $t(67)$ = 3.11, $R^2$ = .38). Hence, respondents who experienced previous victimization (coded as 0 = no, 1 = yes) have more positive interpretations of the ambiguous situation. There was no total effect (path c) found for the group comparisons on the DV, but there was one found for the covariates perceived neighborhood social cohesion ($b$ = .47, 95% *CI* [.20, .73], $t(68)$ = 3.45, $R^2$ = .37) and previous victimization ($b$ = .50, 95% *CI* [.17, .84], $t(68)$ = 3.02, $R^2$ = .37). As perceived neighborhood social cohesion increases, the interpretations of the ambiguous situation become more positive. For those who experienced previous victimization (see coding above) the interpretations are more positive. Finally, there was no indirect or mediation effect found of perceived safety on the relationship between well-maintained UGS and interpretations of ambiguous situations even when covariates were taken into account (a*b = -.01, 95% *BCa CI* [-.08, .06]). It cannot be predicted that the true effect size is different from no effect as CI contains zero, $b^2$ = -.01, 95% *BCa CI* [-.10, .08].

**Figure D1**

*A Mediation Model of 'Hypothesis 2' Including Covariates: Perceived Neighborhood Social Cohesion, Perceived Benefits of Nature, Previous Victimization, Age, Gender, and Nationality*



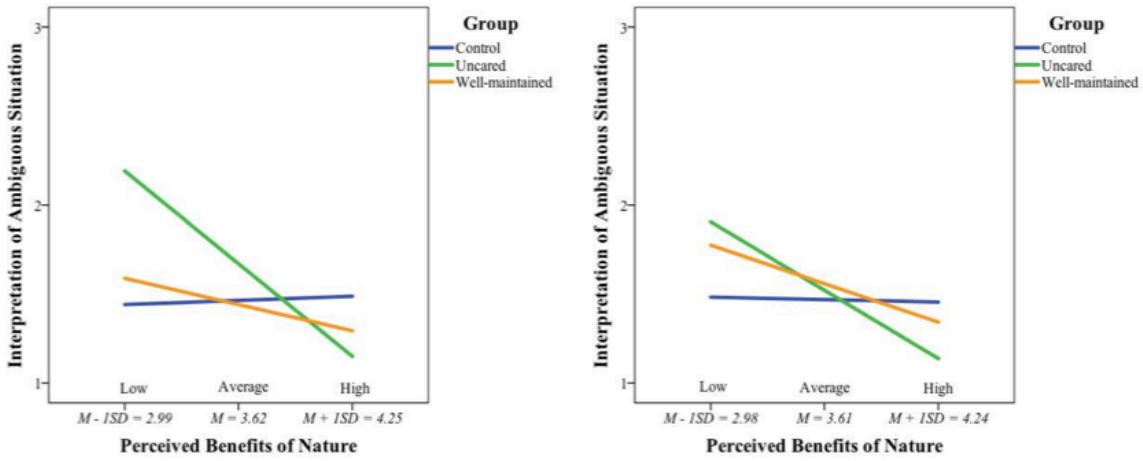

*Note.* *Zero is not included in the 95% CI.

When adding the covariates to the moderation effect as specified in H3, the interaction term between perceived benefits of nature and the UGS variable changed. Unlike before, not even for the uncared UGS group did the interaction with perceived benefits of nature lead to an added amount of variance in the interpretation of the ambiguous situation. As can be seen in Figure D2 the previously observed differences between the groups at lower levels of perceived benefits of nature decreased. Furthermore, there is almost no change in the slope of

the control group, meaning that interpretations of the ambiguous situation did not vary across different levels of perceived benefits of nature. Though, there was a main effect observed between perceived neighborhood social cohesion and the DV ($b$ = .44, $t(77)$ = 3.25) with a 95% *CI* [.17, .71], as well as between previous victimization and the DV ($b$ = .54, $t(77)$ = 3.49) with 95% *CI* [.23, .86]. As perceived neighborhood social cohesion increases, the interpretation of the ambiguous situation becomes more positive as well. Moreover, among respondent's who experienced previous victimization (coded as 0 = no, 1 = yes) the interpretations become more positive. However, previous correlations (see Table 2, p. 19) between these variables revealed only a moderately strong correlation between neighborhood social cohesion and interpretations of ambiguous situation, and a weak correlation between previous victimization and the DV.

**Figure D2**

*Interaction Plots Depicting How UGS (Three Levels) and Perceived Benefits of Nature are Related to the Respondents' Interpretation of the Ambiguous Situation With (Right) and Without (Left) Taking Covariates Into Account*




*Note.* 1 represents a negative, 2 a neutral and 3 a positive interpretation