MASTER

Intelligent dynamic road lighting and perceived personal safety of pedestrians

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Intelligent dynamic road lighting and perceived personal safety of pedestrians

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Learn to reverence night and to put away the vulgar fear of it, for, with the banishment of night from the experience of man, there vanishes as well a religious emotion, a poetic mood, which gives depth to the adventure of humanity.

Henry Beston1880-1968

Preface

This master thesis report you are about to read is the final requirement for my master in Human Technology Interaction. Before I started this study I finished a bachelor in chemical engineering. Although chemistry is interesting, I wanted to broaden my scope. Therefore I started this study at the faculty of Industrial engineering and Innovation sciences. With great joy I followed most of my classes and participated in many projects. Especially the psychological aspects lectured in several classes appealed to me. Because of this interest I've chosen to work on the Intelligent Dynamic Road Lighting project as my master thesis. In retrospection, this turned out to be a good choice with great results. Therefore I would like to thank my supervisors Antal Haans and Yvonne de Kort for their great help and support throughout this project. I've consulted especially Antal many times for advice as well as for practical issues concerning the experiment set up. He always managed to come up with new ideas or practical solutions. Furthermore I would like to thank John Servaes and Bart van den Broek for their assistance during the experimental sessions.

Finally, I would like to thank my family, friends and especially my girlfriend Anneke for their advice and support during the last three years in which I was employed in getting my Master degree.

Thijs van Osch
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Executive Summary

The function of road lighting is to prevent crime, provide a sense of perceived personal safety, as well as the ability to successfully orientate and navigate urban environments at night. However more and more people realize the negative effects of abundant street lighting, such as light pollution and energy consumption. In 2001, 63 per cent of the world population was confronted with night skies brighter than the threshold set for light pollution by the International Astronomical Union (Chepesiuk, 2009). Exposure to light pollution over longer periods of time can have lasting negative effects on the health of both human and wildlife. A second motive for reducing abundant road lighting is sustainable energy usage. The total energy consumption of public lighting in the Netherlands is currently estimated to be 600.000 to 700.000 MWh a year, of which about 500.000 MWh is used for the lighting of infrastructure such as roads, bicycle trials and footpaths (SenterNovem, 2009). Reducing energy consumption and light pollution by road lighting can be realized using intelligent dynamic road lighting systems with LED technology. Such intelligent dynamic road lighting systems can offer light only when and where it is most needed, thereby preventing light pollution and energy waste. However, such dynamic lighting should not negatively affect a pedestrian's perceived personal safety, because fear of crime often elicits a stress reaction, to avoid, to reduce, or to cope with a threatening situation (Riger, 1985). Therefore the addressed research question in this report is "What is the influence of different dynamic road lighting scenarios on perceived personal safety" In particular, where would pedestrian's benefit from light the most e.g. at their own location or in their direct surroundings?

To answer this research question a field study is performed using testbed "de Zaale" on the campus of the Eindhoven University of Technology. "De Zaale" is normal street setting equipped with intelligent dynamic road lighting containing twelve lampposts over a range of 350 metres. A three condition (three different light distributions: darkspot, spotlight, and a control condition) within-subject experiment was conducted with perceived personal safety as the dependent variable. These three light scenarios are designed to have opposing light distributions at the location of the pedestrian, with an equally amount of illumination. To explain differences measured in perceived personal safety Appleton's prospect and refuge theory is used complemented with a social psychological model by van der Wurff and colleagues (van der Wurff, Staalduinen & Stringer, 1989; Appleton, 1975). The dependant variable perceived personal safety and the independent variables prospect, concealment, exposure, escape, attractiveness and power are measured using an equidistant 5-point answering scale questionnaire.

Considering the results the present study demonstrates that the manner in which light is distributed across the poles in an intelligent dynamic road lighting setup influences the perceived personal safety of pedestrians at night. We have shown in an experimental field study that light has an effect on the proximal cues prospect, exposure, concealment and escape. Prospect is indicated to be the most important proximal cue influencing a pedestrians perceived personal safety. The relatively highest level of perceived personal safety is experienced when a pedestrian's personal and action space are sufficiently illuminated. Illuminating these areas increases prospect, exposure an escape, and decreases concealment. Additional illumination in a pedestrian's vista space does not necessarily contribute to the increase of their perceived personal safety. Furthermore individual differences between pedestrians such as gender and attractiveness can enhance the negative effect of poor

illumination on perceived personal safety. This knowledge should be integrated in the future design of an intelligent dynamic road lighting system in order to maximise the personal safety of pedestrians using such a system at night.

1. Introduction

The history of modern road lighting started in the early 12th century. Before that time people were not interested in illuminating roads and city centres because they believed that the night itself should remain unexplored (Bouwman, 1987). However, after the 12th century an increase of activities at night, both commercial and recreational, resulted in a more liberal view on the night itself which encouraged the realisation of road lighting. The urge to implement road lighting was strengthened by the attraction of all kinds of criminals which used the darkness to cover up their criminal activities. At first candles or lamps fuelled by wood, coal and oil were used to light up streets, until in 1780 the Swiss physician Aime Argand invented the Argand gaslight. This new type of technology was used to light up factories, lighthouses, stores, houses, and created the possibility for the implementation of a more effective road lighting system (Lintsen, 1992). The first electrical application of road lighting was introduced in the Netherlands in 1850 only several years after the invention of the light bulb by Thomas Edison. In our current society road lighting and urban design are inseparable. It is used to light up streets, bicycle trials and footpaths. The fundamental functions of road lighting are to prevent crime, to provide a sense of perceived personal safety, as well as to facilitate successful orientation and navigation at night.

Despite the important functions of road lighting, more and more people realize the negative effects of abundant street lighting which is referred to as light pollution. Environmentalists, naturalists, as well as medical researchers define light pollution to be very harmful and one of the fastest growing forms of environmental pollution. These specialists are supported by a substantial amount of scientific research suggesting that light pollution can have long lasting negative effects on the health of both human’s as well as wildlife (Chepesiuk, 2009). In this literature the ecological effects of artificial light at night have been shown to affect both flora and fauna. A second motive for reducing abundant road lighting is sustainable energy usage. The total energy consumption of public lighting in the Netherlands is currently estimated to be 600.000 to 700.000 MWh a year, of which about 500.000 MWh is used for the lighting of infrastructure such as roads, bicycle trials and footpaths (SenterNovem, 2009).

A possible solution reducing both light pollution as well as abundant energy consumption of road lighting is offering light only when and where it is most needed. This can be realized by developing an intelligent dynamic road light system. Such as intelligent dynamic road light system is able to detect pedestrians, define their exact position and the direction he or she is moving. Using the pedestrian’s location and travel direction the system can offer different light distributions which optimize the fundamental functions of road lighting. However, first more insight should be gained on the influence of dynamic road lighting on perceived personal safety, orientation and navigation at night. Therefore the addressed research question in this report is “What is the influence of different dynamic road lighting scenarios on perceived personal safety” In particular, where would pedestrians benefit from light most e.g. at their own location or in their direct surroundings?

1.1 Perceived personal safety

“Perceived personal safety is defined as a general fear of becoming a victim, which is associated with specific social contexts, such as visiting a party or waiting for a bus, or walking home at night” (p. 466, Blobaum & Hunecke, 2005). This fear is dependent on psychological characteristics such as perceived attractiveness and perceived power, as well as on specific physical environmental cues. Some locations are perceived as unsafe because of a criminal history, while other locations are perceived as unsafe, however in reality no crime has occurred. In the first case the location is evaluated as unsafe using objective cues, and in the latter case the location is evaluated as unsafe using subjective cues. Previous studies indicate a significant influence of different physical features in urban environments on perceived personal safety (Nasar & Jones, 1997; Nasar, Fisher & Grannis, 1993; Blobaum & Hunecke, 2005; Loewen, Steel & Suedfeld, 1993). In these studies lighting has shown to be an important physical environmental feature which influences crime rates and perceived personal safety. In a meta-analysis of thirteen studies on the relation between street lighting and crime rates Welsch and Farrington (2008) showed that improved street lighting significantly reduces crime. Furthermore, these results showed that improved street lighting increases perceived personal safety of pedestrians (Blobaum & Hunecke, 2005)(Loewen et al., 1993). The effect of light on safety feelings is generally explained with Appleton's Prospect and Refuge theory which introduces the concepts of prospect (overview), refuge (ability for offenders to hide) and escape (ability to flee).

1.2 Light pollution

Despite the important functions of road lighting, more and more people realize the negative effects of abundant street lighting which is referred to as light pollution. (Navara & Nelson, 2007) In 2001, 63 per cent of the world population is confronted with night skies brighter than the threshold set for light pollution by the International Astronomical Union (Chepesiuk, 2009). In addition, over 80 per cent of the US population, and two third of the population in the European Union regularly frequently experience a sky brightness greater than nights with a full moon (Navara & Nelson, 2007). Finally, approximately 40 per cent of the United States population, one-sixth of the European Union population, and one tenth of the World population cannot look at the sky with the eye adapted to night vision, because its brightness is above the night vision threshold (Cinzano, Falchi, & Elvidge, 2001). An interesting example of the excessiveness of light at night is demonstrated when light disappears. "For example an earthquake in 1994 knocked out the power in Los Angeles, many anxious residents called local emergency centres to report seeing a strange "giant silvery cloud" in the dark sky. What they were really seeing, for the first time, was the Milky Way, long obliterated by the urban sky glow" (p. A21, Chepesiuk, 2009).

An example to illustrate the harmful properties of exposure to street lighting is the disruption in seasonal variations of trees. Artificial light prevents many trees from adjusting to seasonal variations which affects primarily wildlife that depends on trees as their natural habitat (Rich & Longore, 2006). Furthermore research on the effects of light pollution on fauna shows that insects, birds, reptiles and even fish, are affected by light pollution. Light pollution can changes behaviours, foraging areas and breeding cycles (Chepesiuk, 2009). For instance sea turtles hatchlings normally navigate toward the sea by orienting away from the dark silhouette of the landward horizon. If there are artificial bright lights close to the beach they can become disorientated and navigate toward the artificial light source, they then, will never find the sea (Tuxbury & Micheal, 2005). Similarly birds are affected by light pollution during their migration because light attracts birds and disorients them (Longcore & Rich, 2004). Additionally light pollution can have serious implications for the health of humans as well. The exposure to extended periods of bulb light at night can disrupt hormone regulation (Bartness, Demas, & Song, 2002), reduce the effectiveness of one's immune system (Carrillo-Vico, Guerrero, Lardone, Reiter ,2005), and can even decrease the body's resistance to cancer (Schernhammer & Schulmeister, 2004). This risk is supported by statistical figures calculating the risk of developing breast cancer to be up to five times higher in industrialized nations than in underdeveloped countries. Evidence in previous research suggests that high levels of artificial light at night in industrialized societies increase this risk on developing cancer (reviewed in Schernhammer & Schulmeister, 2004). Although light intensities causing this increased risk of breast cancer need to be much higher than the light intensities emitted by street lighting, nevertheless these studies show the negative effects of being exposed to light at night.

1.3 Energy consumption

A second motive for reducing abundant road lighting is sustainable energy usage. Reducing the energy consumption of road lighting does currently not save energy resources because of a surplus of energy production at night. The abundance of electricity arises because electricity production in the Netherlands is realized mostly by coal power stations of which the capacity today isn't adjustable. Therefore they provide the same amount of electricity at night as during the day, even though the demand for electricity at night is much less. If this abundant energy isn't used by road lighting, it will be disposed. Future developments in electricity production with nuclear power plants as well as solar panels can result in a more dynamic energy production capacity. Therefore reduced energy consumption of road lighting can have a significant benefit on the total energy consumption in the Netherlands.

1.4 Intelligent dynamic road lighting

An Intelligent dynamic road lighting system is able to distribute light only when and where it is most needed thereby reducing light pollution and energy waste. During periods with very few of no traffic activities the road lighting can be reduced to a bare minimum. Such a road lighting system should be highly intelligent to detect pedestrians, define their exact position and the direction he or she is moving in. Using the pedestrian's location and its travel direction the system should be able to offer a suitable light distribution which supports the needs of the pedestrian at that particular moment. Using LED technology for the development of an intelligent road lighting system is an obvious choice because the energy efficiency of LED technology in itself is much higher than from conventional high pressure sodium lamps. But more importantly, LED technology affords adaptive and therefore interactive lighting. The illumination output of LED lighting sources is controllable from 0 to 100% which is the main required property necessary for the creation of an interactive road lighting system. Some additional advantages of LED lighting sources are an increased life spam, less diffused lighting and improved color recognition (Brons, Akashi, Freyssinier, Morante & Nonaka, 2010). However a major technical challenge for a successful implementation of an intelligent dynamic road lighting system is the development of an accurate sensing and recognition system which indicates the type and number of user(s). These technical challenges together with the psychological user experience of an intelligent road lighting system are two key factors which determine its success or failure. This master thesis report will focus on the latter and will provide insight in the psychological user experience of intelligent road lighting systems.

2. Fear of Crime

A little over twenty percent of the Dutch population has reported to occasionally feel unsafe in their own neighborhood, and an additional three percent has even declared to frequently feel unsafe (www.cbs.nl, 22/07/2010). This makes fear of crime a much bigger problem than crime itself because fear of crime directly affects many more people than actual crime does (Evans & Flecther, 2000). Fear often elicits a stress reaction, to avoid, to reduce, or to cope with a threatening situation (Riger, 1985). As such, fear of crime is an urban background stressor that threatens people's quality of life, and restricts mobility (Nasar & Jones, 1997). Fear of crime has an uneven distribution over space, time and populations. Some groups such as the poor, elderly, and women experience higher levels of fear than others (Nasar & Jones, 1997). For instance, even though men generally have more experiences with physical violence than women, they seem less affected by fear of crime (Blobaum & Hunecke, 2005). This difference in perceived personal safety between men and women is partly explained by the association with different kind of incidents. Men more readily anticipate a fight, whereas women mainly fear rape. A women walking alone in a park after dark might fear the risk of a sexual assault because she is simply being perceived as a woman and thus as a potential rape victim (Blobaum & Hunecke, 2005).

2.1 A Social Psychological model

The fear of crime can be conceptualized in a social psychological model by Van der Wurff and colleagues (van der Wurff, Staalduinen & Stringer, 1989). This model is based on the assumption that fear of crime is associated with four social psychological components; Attractiveness, Evil intent, Power, and the Criminal space. The first component refers to the potential victim, the second to the potential offender, and the third component refers to both of these parties. The fourth and last component describes the physical environment in which the crime may take place.

2.1.1 Attractiveness

Attractiveness refers to the degree in which people see themselves or their possessions as an attractive target or victim for criminal activities. By this we mean the attribution of a characteristic to oneself, or a value to one's possessions" (van der Wurff et al., 1989). Consider for example the special feeling one may have when walking on the street with a large amount of money. The extent to which potential victims evaluate their level of *Attractiveness* as a crime target is dependent on demographic variables, such as age and sex. In a British Crime Survey young women gave fear of rape as a first response when asked which crime they feared the most (Maxfield, 1987). In contrast, elderly women were more concerned about mugging instead of fearing a potential rape. Research shows that rape produces more serious and longer lasting traumas which are far worse than what is experienced by victims of robbery and other crimes (Resick, 1987). This shows that young women perceive themselves as a more attractive target for sexual assault and a less attractive target for mugging, whereas elderly women perceive the opposite.

2.1.2 Evil intent

The *Evil Intent* component refers to the offender's role in a threatening situation. It represents the extent to which a person attributes criminal intentions to another individual or particular group (van der Wurff et al., 1989). For instance one could feel uneasy passing a group of adolescents who are meeting in the park because they are known to harass others. Or, one could be suspicious to persons wearing a cap or hooded sweater concealing their face, thereby making them unrecognizable.

2.1.3 Power

Power refers to the possibilities a person has to defend oneself to possible threats of assault by another. This can include the degree of self-assurance and feeling of control one possesses in facing threatening situations (van der Wurff et al., 1989). The Power component can refer either to one's own power or to the power of a potential offender. One's own power describes a person's confidence in his or her own defence capabilities. If a person is very immobile like elderly or some physical impaired persons, he or she will not be able to flee from a threatening situation even though the environment facilitates escape possibilities. Therefore they will perceive themselves to have very little power.

The *Power* of the other is in this description equally important. It concerns characteristics attributed to potential offender such as their strength dexterity and general ability to carry out their criminal intentions (Farrel, Bannister, Ditton & Gilchrest, 2000). A comparison between the power one attributes to oneself en the perceived power of the other determines if one could face a possible confrontation with confidence or not. Therefore the belief that youngsters nowadays often carry weapons can lead to feelings of fear if one has no compensating power. Again, the way potential victims determine their own *Power* and the *Power* of a possible offender is closely related to the demographic variables age and sex. Men for example more easily anticipate a fight than women. However when they become older and less fit to defend themselves they experience and increased level of fear because they still anticipate a fight (Blobaum & Hunecke, 2005). Furthermore they become less mobile to escape from a possible threat, although this, of course, applies to elderly woman as well (Clarke, Ekblom, Hough & Mayhew, 1985). Additionally the fear of crime increases with age because the consequences of physical injuries obtained during an assault have serious consequences for elderly because they may need a long recovery time, if they will recover at all (Killias, 1990). This thought can threaten their autonomy which results in an increased fear of crime because of decreased fitness and mobility (Killias, 1990).

2.1.4 The Criminal space

The Criminal space is the fourth and final component covered by this model. The *Criminal space* component describes the physical environmental features in which a crime may take place (van der Wurff et al., 1989). This component focuses on characteristics of place and time and on the presence of others. The criminal space describes the extent to which a physical environment is perceived as facilitating the possibility of a criminal activity in the eyes of a possible victim. An example of a criminal environment that easily facilitates criminal activities is a bicycle track surrounded by dark wood. Possible offenders have plenty of possibilities to hide in the bushes or behind a tree to prepare and execute their criminal intentions without being seen. Again this component can be perceived differently by people and therefore assessed differently.

Prospect and refuge

Many studies show a clear relation between different evaluated physical features of the urban environment and perceived personal safety. Environmental cues determine if a physical environment is perceived as safe or unsafe. Graffiti is such an environmental cue which because of its association with criminal activities can reduce a person's perceived personal safety. Therefore the immediate environment of a subway or city wall covered with graffiti can be perceived as less safe than unsprayed objects, even thought this has nothing to do with actual safety. This means that the subjective evaluation of a designed urban environment significantly influences the experienced level of perceived personal safety by its inhabitants in that environment (Nasar, Frisher & Grannis, 1993; Nasar & Jones, 1997). Appleton explains three important environmental cues in his prospect-refuge theory (Appleton, 1975). According to this theory prefer humans a place with refuge (a place of concealment) and prospect (an open view) because such places allow them to survey their surroundings from a place of protection. An example of offenders favouring places which combine concealment from which to view the situation, and enough prospect to maintain control of the situation was observed on tapes which contained video images of a bank robberies (Archea, 1985). The bank robbers consistently used their environment to control their prospect and their own visibility (seeing and being seen). They used their environment to their advantage by using physical features such as furnishings or columns to conceal their activities and prepare their attacks (Wise & Wise, 1985).

However there is an ambiguity in this theory because it applies to both potential victims as well as to potential offenders. Refuge can mean protection for a potential victim or for a possible attacker. Therefore, Nasar speaks of the dual affordances of the same physical environment as "offering the observer perceived protection or refuge; but…. affording concealment for a potential attacker" (p. 128, Nasar, 2000). In other words, a potential victim would feel most safe in a place that offers open prospect and no refuge for an offender, whereas an offender may prefer a place offering places of concealment, thereby reducing the prospect of the target. To reduce this ambiguity in the concept of refuge between victims and offenders in Appleton's prospect and refuge theory, we subdivide refuge in concealment and exposure. Refuge concerning a potential victim is redefined as Exposure, and refuge concerning an offender is redefined as Concealment. An environment with many places of concealment influences safety in a negative way because it can cover a possible offender outside the line of sight, which feeds uncertainty resulting in a decreased perceived personal safety (Nasar et al., 1993). A place of concealment creates the inability for victims to spot danger in an early stage giving them no possibilities to escape from it (Nasar et al., 1993). Therefore places of concealment for possible offenders create poor prospect for potential victims. Exposure on the other hand, covers the level to which a pedestrian feels himself to be exposed and vulnerable to possible threats. If environmental properties create a situation in which a pedestrian is very exposed, potential attackers can asses in an early stage if the intended victim is an attractive target and whether he or she possesses Power to defend or escape. This increases the vulnerability of the intended victim and therefore a high level of exposure influences perceived personal safety in a negative way.

Escape

In the case of an actual attack by an assailant the victims will try to escape from their offenders when they feel unable to defend themselves. In this case, it will be most important that no surroundings impede his or her escape (Appleton, 1975). Consequently, anticipated entrapment will evoke fear, even if there is no potential offender around (Nasar, Frisher & Grannis, 1993; Nasar & Jones, 1997). Therefore physical features that inhibit individuals from a possible escape have a large impact on individual's perceived personal safety. A clear example of an environment with few possibilities for escape is a bridge with a low balustrade (Blobaum & Hunecke, 2005). Although the elevated position provides good prospect, the balustrade doesn't provide any possibilities to escape. This example shows that the amount of fear experienced in a certain environment depends on the interaction between its physical features. Some environmental features influence both prospect, refuge and entrapment, while other just influence one of these three components.

Again, demographic variables such as sex and age play a large role in the effect of escape possibilities on perceived personal safety. Although in case of an actual assault possibilities of escape will become relevant for both men and women, possibilities for escape seem to be even more important for women than for men. Most women judge escaping as the most adequate behavior if ambushed, whereas some men may just as readily respond to an attack by fighting (Blobaum & Hunecke, 2005). This reasoning also applies to elderly men and is emanated from the perceived personal power to defend oneself, as included in the psychological component *Power*.

2.2 The influence of lighting on fear.

Darkness is reported to be an extreme factor causing places of concealment for potential offenders and uncertainty for potential victims resulting in decreased levels of perceived safety by potential victims (Warr, 1990). This was validated in a study by Nasar and Jones who reported two kinds of physical concealment cues: objects (trees, shrubs, vehicles, walls, alcoves) and patterns of darkness and shadow (Nasar & Jones, 1997). Therefore they suggest that the use of appropriate lighting, strategically placed, can increase perceived personal safety because bright and accurate diffused lighting has the ability to reduce shadows and eliminate dark spots. As mentioned before, pedestrians prefer places with overview (prospect) and concealment (refuge). Shadows and darkness do not permit pedestrians to have a clear overview of the surrounding environment. Additionally darkness allows possible offenders to conceal themselves which increases uncertainty. Therefore, urban environments with poor illumination have poor overview and a large ability for offenders to hide, which decreases perceived personal safety (Blobaum & Hunecke, 2005; Loewen et al., 1993). The influence of light on prospect, concealment and anticipated entrapment determine to a large extent how these environmental cues are experienced and interpreted. Lighting seems to be especially relevant in situations with a low level of entrapment, because a change of lighting conditions may become relevant in settings already offering possibilities to escape, whereas places containing high levels of entrapment might not profit from improved lighting (Blobaum & Hunecke, 2005). Summarized, appropriate and strategically placed lighting should provide prospect which is important for the anticipation of danger as early as possible. Additionally it should reduce concealment possibilities for offenders, and allow victims to identify possibilities to escape in threatening situations.

The effect of light quality on exposure is equally important for the influence of lighting on fear of crime. If a person is walking down a street that is equipped with much road lighting, this person will be very exposed and thereby perceived very easily by others. As discussed earlier, this makes them vulnerable because it gives possible offenders the opportunity to asses if this person is an attractive target or, if he or she possesses the ability to successfully defend oneself.

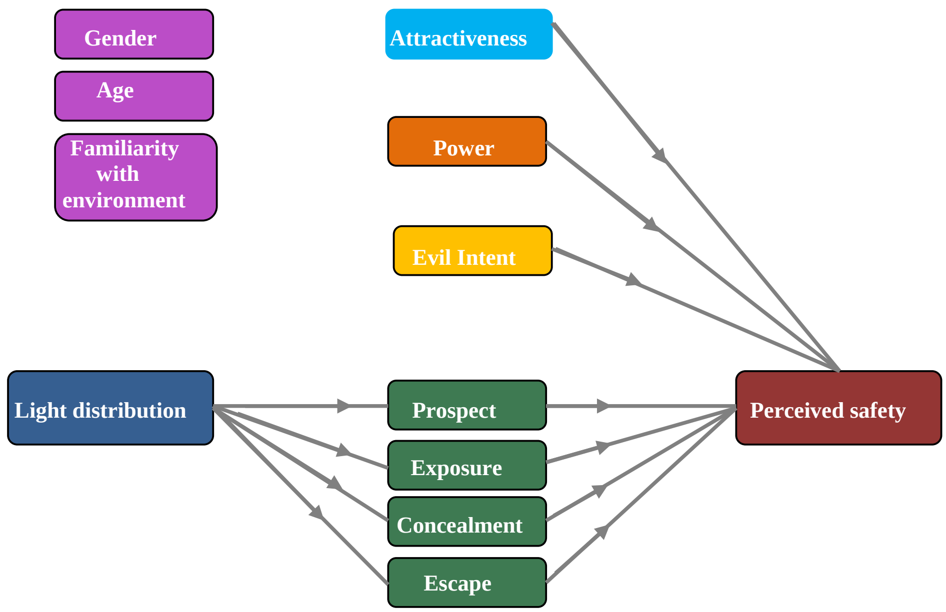

Figure 1. Schematic illustration of theoretical model.

2.3 Research questions

The discussed theory already supports a clear relation between environmental features, road lighting and perceived personal safety. However, these studies were all performed using static road lighting instead of dynamic road lighting. For example in research by de Kort and Haans on the evaluation of static light distributions, participants indicated a preference for static light distributions that focus on their own location, instead of their direct surroundings by feelings of safety (De Kort, Haans, Geerdinck, van Gennip, Horst & Servaes, 2010). In this follow up research, we introduce for the first time a field study performed with dynamic road lighting. The main goal of the study is to analyze the influence of different dynamic road lighting scenario's on perceived personal safety of pedestrians. Previous studies have already supported the relevance of physical environmental features for perceived personal safety (Nasar, Frisher & Grannis, 1993; Nasar & Jones, 1997), and related improved road lighting to an increased level of perceived personal safety (Blobaum & Hunecke, 2005; Loewen et al., 1993). However dynamic road light scenarios were not included in these studies which leave room for supplementation. In this study the central research question will be; "Where would pedestrian's benefit from light most: in their surroundings (e.g. their vista space) or at their own location (e.g., their personal and action space)". To answer this research question three different road lighting scenarios, with different light distributions focused to create different levels of prospect, concealment, exposure and escape are compared. The first scenario facilitates light in the pedestrians vista space (e.g. more than 30 metres from the pedestrian), whereas the second scenario facilitates light in a pedestrians personal space and action space (e.g. less than 30 metres from the pedestrian). The third scenario is less extreme in the differences in light distribution and facilitates illumination in both the pedestrians personal and action space as well as in their vista space, however with lower concentrations.

An additional second interest is how the relation between dynamic road lighting scenarios and perceived personal safety can be explained. We would like to explain how the concepts of Prospect, Exposure, Concealment and Escape influence perceived personal. Therefore the following additional sub research question will be examined; "How can the effect of different dynamic road lighting scenarios on pedestrians perceived personal safety be explained by the variables prospect, concealment, exposure and escape?" In Figure 3 the three compared lighting scenarios are illustrated. These scenarios are designed based on inferences from the prospect-refuge theory by Appleton (Appleton, 1975).

Expectations based on previous studies are translated into the following four hypotheses:

Hypothesis H1: Dynamic light distribution differences affect personal safety experienced by pedestrians.

Hypothesis H2: The differences in perceived personal safety in different light scenarios can be explained by the concepts of prospect (overview), concealment, exposure and escape (ability to flee).

Hypothesis H3: Pedestrians feel safer in a light distribution which offers light in their vista space instead of in their personal and action space, because it positively influences the proximal cues Prospect, Exposure, Concealment and Escape.

Hypothesis H4: Gender, attractiveness and power affect perceived personal safety experienced in different light distributions.

3 Methods

3.1 Design

A three condition (light distributions: darkspot, spotlight, control condition) within-subject experiment was conducted with perceived personal safety as the dependent variable. The interactive road lighting test bed “de Zaale” on the campus of the Eindhoven University of Technology will was used to address the research question. The different light distributions illuminated the participant travelling down the street differently in each condition. These road light scenarios were counterbalanced between subjects. The dependent variable perceived personal safety was measured by means of a questionnaire. The questionnaire also included items regarding the proximal cues prospect, exposure, concealment, and escape. At the end of the experiment (i.e., after exposure to all three lighting conditions), participants completed a second questionnaire on the personal characteristics attractiveness, power as well as the demographic variables gender, age and familiarity with the environment.

Figure 2. Road lighting lamppost equipped with both led unit (working) and high pressure sodium lamp

3.2 Participants

Our sample was drawn from the participant database of the JF Schouten School at Eindhoven University of Technology, Eindhoven, the Netherlands. Fifty persons were invited to participate in the experiment. All participants were native Dutch speaking, and mostly undergraduate students from the Eindhoven University of Technology or surrounding institutes. The mean age was 21.8 (*SD* = 2.5; range 18 to 27 years). Twenty-eight of the participants were men. All participants received a compensation of € 10.00. The direct surrounding of testbed “de Zaale” was experienced as safe by these participants with a mean of 4.8 (SD= 1.12) judged on a six point measuring scale from unsafe to safe.

3.3 Setting & Apparatus

3.3.1 Light scenario design

Test bed “de Zaale” is a connection road for cars travelling from West to East or vice versa over the private TU/e campus. The testbed contains twelve lampposts about thirty meters apart from one another in a range of 350 metres. These lampposts are besides conventional high pressure sodium lamps equipped with LED lighting units (Figure 2&3). Such lighting units provide the ability to adapt illumination output which makes it possible to control the light dispersion quantity from one to one hundred percent. Individual luminaries are operated by a control system which creates the possibility to program different lighting scenarios.
The study is focused on the perceived personal safety of pedestrians. Therefore the road lighting used in testbed “de Zaale” should be equipped for pedestrian instead of motorized traffic. However different light intensities and a different lamppost design is used in testbed “de Zaale” to facilitate motorized traffic. The lampposts are taller and placed further apart from one another. The differences in lighting intensities of outdoor lighting are qualified in illumination categories, and because testbed “de Zaale” is equipped with road lighting intended for motorized traffic it produces a maximum of 25 lux. The illumination category for pedestrians in residential areas (S1/S7) has a maximum of 15 lux (European Standard EN 1320-2). To compensate differences in illumination intensity the maximum output of the LED lighting units is set at 80%. Illumination measurements directly under a lamppost activated at 80% lighting output, show light intensities of about 12 lux at street level. This is 3 lux under the maximum of the residential areas which creates similar lighting properties. The minimum output of the lighting units is set at 1% instead of 0%, to prevent that lighting units appear broken.

To make a reliable comparison of effects between conditions, the total amount of light emitted between conditions is equal. This means that the sum of the percentages of light emitted by the lighting units is similar between conditions. Every road light setting includes 3 or 4 lampposts at the same time, covering a distance of about 90 or 120 meters. Figure 3 illustrates schematically the differences between conditions. In the darkspot scenario the pedestrian is travelling in a dark area between two lampposts with an output of 1% surrounded by two lampposts with an output of 80%. The other lampposts on the testbed, besides the ones used, are set at 1%. When the pedestrian passes the next lamppost, the scenario gradually changes in four steps of each 3.75 seconds to its new light setting. This means that it takes approximately 15 seconds to change the light distribution to the next 3 or four lampposts, which is the average time it takes a pedestrian to reach the next lamppost. This is repeated until the pedestrian reaches the end of the testbed. The spotlight scenario behaves similarly, however the pedestrian travels in between two lampposts with an output of 80% creating a spot of light exposing him or her. The surrounding lampposts on the testbed are set at 1%. The third condition, the control scenario, has similar properties as scenario one and two however uses three poles instead of two. The pedestrian is travelling in between two lampposts with a lighting output set at 54%. Additionally, an extra lamppost in front of the pedestrian is set at 54% illumination output as well. Again, surrounding lampposts on the testbed are set at 1%. For the exact light setting per lamppost see appendix D.

Scenario Darkspot has a light distribution which has a low level of illumination at the location of the pedestrian and a high level of illumination in the direct surroundings. This makes the pedestrian very poorly lit which creates a place of concealment in the dark (low exposure), and at the same time is the direct surrounding of the pedestrian sufficiently illuminated to have a good overview (high prospect/high escape/ low concealment). Road light scenario Spotlight has opposite lighting distribution properties compared to the Darkpsot scenario, and therefore the Spotlight scenario has opposite expectations regarding the evaluation of environmental cues. In the Spotlight scenario the location of the pedestrian has a high level of illumination (high exposure), whereas in the direct surroundings low light levels are distributed (low prospect/low escape/high concealment). The pedestrian is illuminated very well and has therefore very few possibilities to conceal him or herself in the dark (high exposure). Additionally, direct surroundings with a low level of illumination create limited overview for the pedestrian (low prospect). Scenario Control is the control setting generating a lower level of equally distributed illumination opposed to the Darkspot and the Spotlight scenarios. Expectations are that participants will prefer scenario Darkspot over scenario Spotlight and scenario Control, whereby this preference is explained by a high level of prospect, a low level of concealment, a low level of exposure and a high level of escape

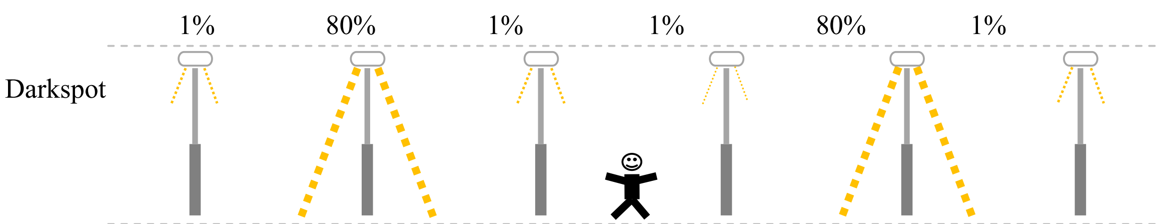

Figure 3. Schematic illustration of light distribution scenarios part 1

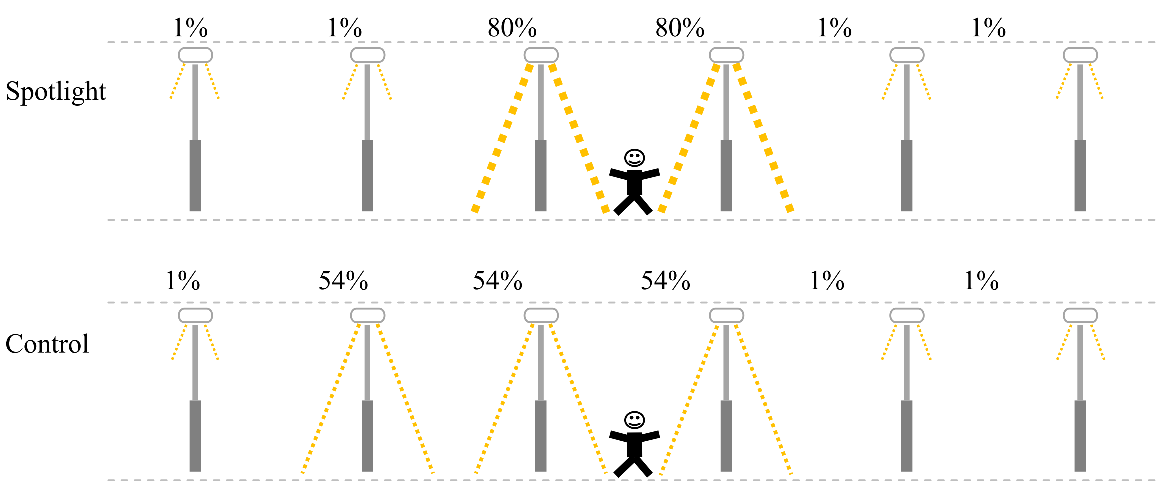

Figure 3. Schematic illustration of light distribution scenarios part 2.

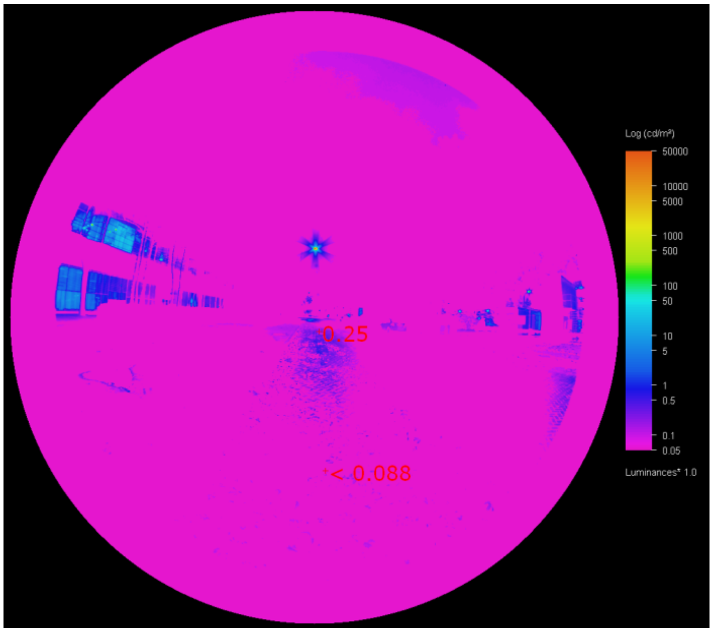

Figure 4.
Illumination foto
Darkspot scenario

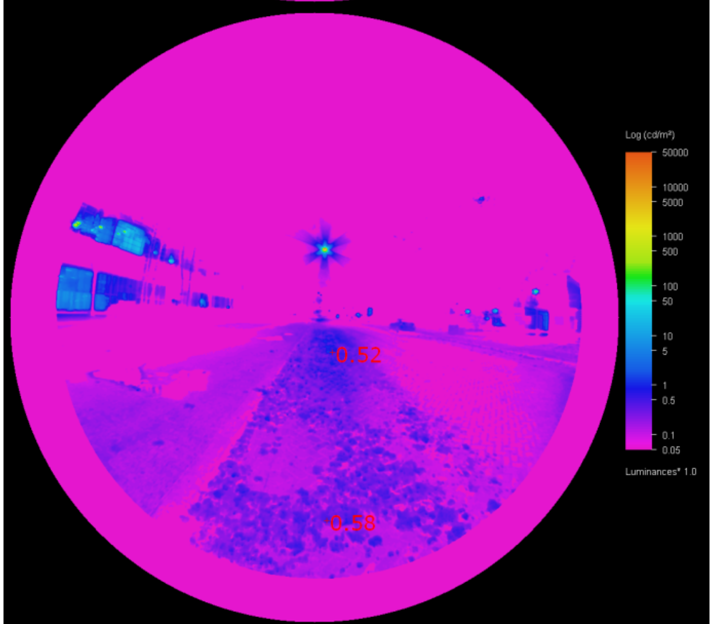

Figure 5.
Illumination foto
Spotlight scenario

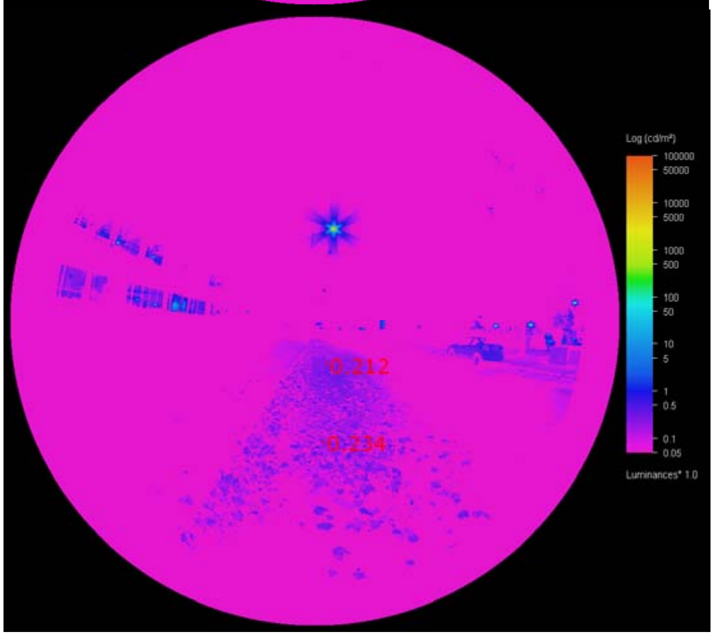

Figure 6.
Illumination foto
Control scenario

3.4 Procedure

Participants were individually invited at road lighting test bed “de Zaale” on the campus of the Eindhoven University of Technology after nightfall in late September. Upon arrival, participants received written and verbal instructions (see appendix A). After instructions, participants were asked to walk over the “the Zaale” in three sessions. They were given a handheld transceiver with the instruction to press the signal button every time they passed the next lamppost. Thus in total they were expected emit twelve signals. These signals were used by the operator of the intelligent road light system in order to define the location of the participant and adjust the light distribution accordingly. In each session they were exposed to a different light distribution (see figure 3). The presentation of light scenarios was counterbalanced between participants. For the first session the participant walked from meeting point A to meeting point B (see figure 7). Arriving at meeting point B the participant filled out questionnaire one. For the second session the participant walked from meeting point B to meeting point A. Arriving at meeting point A the participant had filled out questionnaire one for a second time. In the third session participants walked for a second time form meeting point A to meeting point B. Arriving at meeting point three participants filled out questionnaire one for a third time and last time. After completion of questionnaire one, the participant filled out questionnaire two. After that the experiment was finished. Participants were kindly thanked for their cooperation, and paid before leaving.

Figure 7. Overview testbed “de Zaale

3.5 Measures

As mentioned before, questions were presented to subjects in two parts, during and after the experiment. The complete list with items included in questionnaire one and two can be found in appendix A.

3.5.1 Questionnaire one

Perceived personal safety: Three items were developed to measure the dependent variable perceived personal safety. Questions were designed based on items from a questionnaire developed by Blobaum and Hunecke (2005). Items were included such as “How safe or unsafe did you feel while you walking down this street?” Participants could respond on a five-point scale with labels ranging from, for example, "unsafe" (coded with a 1), through "neutral" (coded with a 3), to "safe" (coded with a 5). The mean score across these three items was used in the analyses. The reliability (Cronbach’s alpha) of this aggregated scale was 0.83 on average (i.e., across the three conditions). There were no missing responses.

Prospect: To measure the proximal cue “prospect” three items were designed based on Appleton’s prospect and refuge theory (Appleton, 1975). An example of a question measuring prospect is “How well or poorly was your overview over this street?” Participants could respond on a five-point scale with labels ranging from, for example, "bad" (coded with a 1), through "neutral" (coded with a 3), to "good" (coded with a 5).The mean score across these three items was used in the analyses. The reliability (Cronbach’s alpha) of this aggregated scale was 0.87 on average (i.e., across the three conditions). There were no missing responses.

Exposure: The proximal cue Exposure was measured using three items specially designed to measure this dependant variable. Question were included such as “How visible or invisible did you feel in this street?” Participants could respond on a five-point scale with labels ranging from, for example, "invisible" (coded with a 1), through "neutral" (coded with a 3), to "visible" (coded with a 5). The mean score across these three items was used in the analyses. The reliability (Cronbach’s alpha) of this aggregated scale was 0.81 on average (i.e., across the three conditions). There were no missing responses.

Concealment: The proximal cue Concealment was measured using three items specially designed to measure this dependant variable. Concealment was measured using questions like “How easy or hard can people with bad intentions conceal themselves in this street?” Participants could respond on a five-point scale with labels ranging from, for example, "hard" (coded with a 1), through "neutral" (coded with a 3), to "easy" (coded with a 5). The mean score across these three items was used in the analyses. The reliability (Cronbach’s alpha) of this aggregated scale was 0.89 on average (i.e., across the three conditions). There were no missing responses.

Escape: To measure the proximal cue “escape” three items were designed based on Appleton’s prospect and refuge theory (Appleton, 1975). An example of a question measuring escape is “How easy or hard can you bring yourself to safety in this street?” Participants could respond on a five-point scale with labels ranging from, for example, "hard" (coded with a 1), through "neutral" (coded with a 3), to "easy" (coded with a 5). The mean score across these three items was used in the analyses. The reliability (Cronbach’s alpha) of this aggregated scale was 0.76 on average (i.e., across the three conditions). There were no missing responses

3.5.2 Questionnaire two

Attractiveness: To measure the level of perceived attractiveness of participants, three items were designed based on the "attractivity" measure by Van der Wurff et al. (1989). Questions were included such as "To what extent do you see yourself as an attractive target for possible criminals?" Participants could respond on a five-point scale with labels ranging from, for example, "unattractive" (coded with a 1), through "neutral" (coded with a 3), to "attractive" (coded with a 5). However the second item "To what extend do you see your possessions as an attractive target for possible criminals?" did not measure the same underlying variable than the other two items. Therefore this question was excluded from the analyses. The mean score across these three items was used in the analyses. The reliability (Cronbach's alpha), without the second item, of this aggregated scale was 0.61 on average (i.e., across the three conditions), which is poor but acceptable. There were no missing responses.

Power: To measure the level of perceived power of participants, three items were designed based on the power measure by Van der Wurff et al. (van der Wurff, Staalduinen & Stringer, 1989). An example of questions that were included is "To what extent do you think you are capable of defending yourself against an attacker?" Participants could respond on a five-point scale with labels ranging from, for example, "incapable" (coded with a 1), through "neutral" (coded with a 3), to "capable" (coded with a 5). The mean score across these three items was used in the analyses. The reliability (Cronbach's alpha) of this aggregated scale was 0.88 on average (i.e., across the three conditions). There were no missing responses.

4 Results

4.1 The effect of light distribution on perceived personal safety

Average perceived personal safety by participants in the control condition was M = 3.84 with SD = 0.81. In the darkspot and spotlight condition average perceived personal safety was M = 3.19 with SD = 1.09, and M = 3.89 with SD = 0.87, respectively. A three condition (light distribution: Darkspot vs. Spotlight vs. Control) repeated measures ANOVA was conducted to test statistically the differences in perceived personal safety of participants between the three different light distributions. Assumptions of normality and sphericity were met. We found a statistically significant main effect of light distribution on perceived personal safety with $F(2, 98) = 14.03$, and $p<0.001$. Further pair-wise comparisons (LSD), showed that participants experienced lower levels of perceived personal safety in the darkspot condition as compared to the spotlight and control conditions, with $t(49) = -4.495$, $p <.001$. In contrast, the difference in perceived personal safety between the spotlight and control conditions was not found to be statistically significant with $t(49) = 0.318$, $p =.752$. To explain these observed differences in perceived personal safety differences, the effect of the proximal cues prospect, exposure, concealment and escape on perceived personal safety are analyzed using a Linear Mixed Model (LMM).

4.2 Mediaton analysis: Prospect, Exposure, Concealment and Escape

The approach to determine mediation according to Baron and Kenny includes three steps and a Sobel significance test (1986). Step one is the assessment of the so-called total effect of light distribution on perceived personal safety. Step two is the assessment of the effect of light distribution on each of the four proposed mediators. These analyses provide the first stage of the indirect effects of light distribution on safety through the proposed mediators. In the third step we test the second stage mediation effects of the four mediators on perceived safety, and the remaining direct effect (C') of light distribution on perceived safety (i.e. the effect that cannot be explained by the mediators Prospect, Exposure, Concealment and Escape). Comparing the remaining direct effect (C') with the total effect, calculated in step one, provides an indication of the level of mediation (e.g. partial or complete mediation). For and illustration of the mediation model see Figure 8.

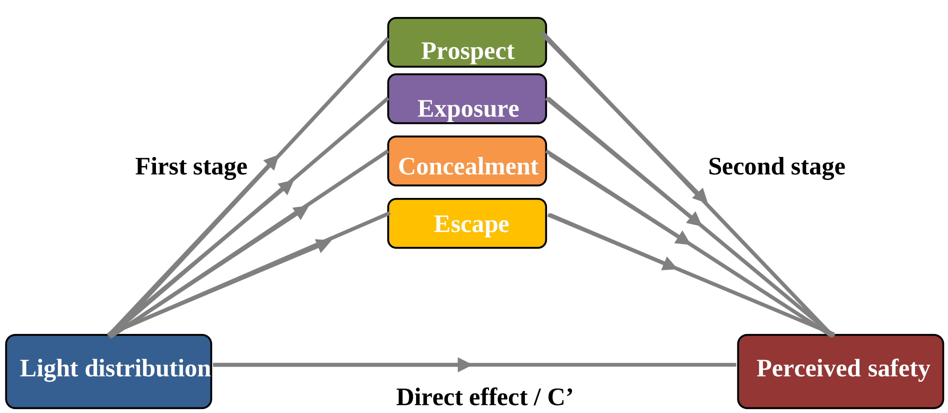

Figure 8. Schematic illustration mediation analysis.

In the next session, each of these steps is conducted using Linear Mixed Models (LMMs). Based on these analyses, Sobel-tests were performed on each of the four mediators. Since the Sobel test requires regression weights, only pair-wise comparison of lighting conditions can be performed. We report on only the difference between the darkspot and Spotlight conditions because of their opposing light distribution properties.

4.2.1 Mediation of Light distribution on Perceived personal safety

For the first step in the mediation analysis, a LMM is performed with perceived safety as the dependent variable, light distribution as a fixed factor and participant number as a random factor. Result revealed a significant (p < 0.001) total effect of light distribution on perceived personal safety with a regression coefficient of B = 0.70 (*SE* = 0.15) In other words, differences in light distribution influences the level of perceived personal safety experienced by participants. For the second step in the mediation analysis, four individual LMMs were performed with in each case one of the four mediators (i.e. prospect, exposure, concealment and escape) as dependent variables, light distribution as a fixed factor and participant number as a random factor. Results show a significant (p < 0.001) first stage mediation effect of light distribution on Prospect with a regression coefficient of B = 0.75 (*SE* = 0.19) and a first stage mediation effect of light distribution on Concealment with a regression coefficient of B = 1.09 (*SE* = 0.17). Result also show a significant (p = 0.002) first stage mediation effects of light distribution on Concealment with a regression coefficient of B = -0.49 (*SE* = 0.15) and marginal significant (p = 0.002) first stage mediation effect of light distribution on Escape with a regression coefficient of B = 0.21 (*SE* = 0.11). In other words differences in light distribution influence the proximal cues prospect, exposure, concealment and escape.

Table 2. First stage mediation effects.

First stage mediation			
	B	*SE* B	*p*
Prospect	.75	.19	<.001
Exposure	1.09	.17	<.001
Concealment	-.49	.15	.002
Escape	.21	.11	.057

In the third step a LMM was performed with perceived safety as dependent variable, light distribution as a fixed factor, and prospect, exposure, concealment and escape as covariates, and participant number as a random factor. Results show a marginal significant (p = 0.053) direct effect of light distribution on perceived safety with a regression coefficient of B = 0.08 (*SE* = 0.13). Comparing this result to the result of step one in the mediation analysis reveals a regression coefficient change from B = 0.70 to B = 0.08 which indicates almost complete.

Furthermore results of the LMM analysis show a significant (p < 0.001) mediation effect of prospect with a regression coefficient of B = 0.46 (*SE* = 0.08) and a marginal significant (p = 0.067) mediation effect of Exposure with a regression coefficient of B = 0.13 (*SE* = 0.07).

Result also show a significant (*p* = 0.004) mediation effect of escape with a regression coefficient of B = 0.28 (*SE* = 0.09), however no significant (*p* = .126) mediation effect was shown by the results with a regression coefficient of B = -0.13 (*SE* = 0.07).

Table 3. Second stage mediation effects.

Second stage mediation			
	B	*SE* B	*p*
Prospect	.46	.08	<.001
Exposure	.13	.07	.067
Concealment	-.13	.08	.126
Escape	.28	.09	.004

Based on the analysis above, we performed a Sobel test (one-sided) for each of the four proposed mediators. We found that the indirect effect of light distribution of safety to be statistically significant for Prospect and Exposure. This means that the effect of light distribution on perceived personal safety experienced by participants can be partly explained significantly by the proximal cues prospect and Exposure. In contrast, we found marginally significant indirect effects for Concealment and Escape. The weights of the mediators indicate that Prospect is most important in explaining the difference in perceived personal safety between the darkspot and spotlight conditions.

Table 4.. Sobel statistics and mediation weights.

Indirect mediation paths			
	Sobel statistic	*p*	*Weight*
Prospect	3.25	<.001	.345
Exposure	1.78	.037	.142
Concealment	1.45	.072	.064
Escape	1.63	.052	.059

One side significance of Sobel statistics

4.3 What is the effect of gender, power and attractiveness on perceived safety?

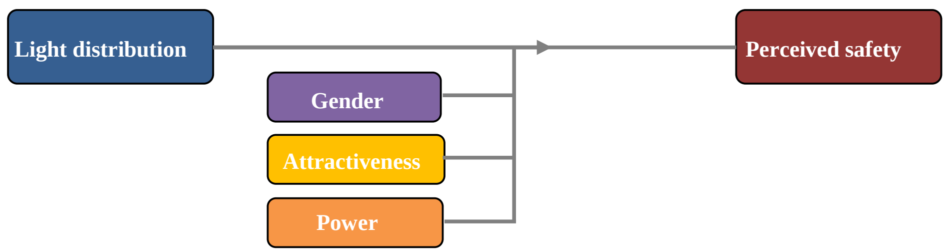

Figure 9. Schematic illustration moderation analysis

Gender

To assess the influence of gender on the total effect of light distribution on perceived safety, a three condition (light distribution: Darkspot vs. Spotlight vs. Control) repeated measures ANOVA was conducted to test statistically the differences in perceived personal safety between men and women. Assumptions of normality and sphericity were met. We found a statistically significant main effect of light distribution on perceived safety with $F(2, 98) = 15.72$, $p<0.001$ and $\eta^2_{partial}$ of 25%. Results revealed a significant ($p = 0.008$) main effect of gender on perceived personal safety with $F(2, 98) = 5.76$ with an $\eta^2_{partial}$ of 11%. Additionally results showed a marginal significant ($p = 0.062$) gender by light distribution moderation (interaction) effect of $F(2, 98) = 2.88$ with an $\eta^2_{partial}$ of 5.7%. This means that the effect of light distribution on perceived safety is different for people with different gender.

Two individual repeated measures ANOVA's for both men and women are performed to assess differences in the influence of light distribution on perceived safety for men and women. Assumptions of normality and sphericity were met. Women show significant ($p<0.001$) different levels of perceived personal safety experienced in different light distributions $F(2, 98) = 10.25$, with an effect size of 33%. They rated the Control distribution as safest (M = 3.77, SD = 0.93), the Darkspot scenario as most unsafe (M = 2.72, SD = 1.00), and in the Spotlight distribution a middle value (M = 3.64, SD = 0.86) of safety was perceived. For men different results are shown. Men show significant ($p = 0.008$) different levels of perceived personal safety experienced in different light distributions $F(2, 98) = 5.22$, with an effect size of 16.2%. They rated the Spotlight distribution as safest (M = 4.08, SD = 0.84), the Darkspot scenario as most unsafe (M = 3.54, SD = 1.04), and in the Control distribution they experienced a middle value (M = 3.89, SD = 0.70) of safety. These results indicate that there is less variation perceived in safety by men than by women. This leads to conclude that the light distribution have a larger effect on safety experienced by women than by men.

According to the conceptualized social psychological model by Van der Wurff and colleague's differences in gender can be explained by perceived attractiveness and perceived power (van der Wurff, Staalduinen & Stringer, 1989). And indeed, our female participants perceived themselves to be more attractive (M = 2.00, SD = 0.69) and less powerful (M = 3.60, SD = 0.87) than male participants M = 3.25, SD = 0.62 and M = 2.24, SD = 0.94 respectively. The difference in perceived attractiveness between men and women was found to be statistically significant with $t(48) = 6.58$, $p < .001$, and the difference in perceived power between men and women was found to be statistically significant with $t(48) = 4.50$, $p < .001$

Attractiveness

To assess the influence of attractiveness on the total effect of light distribution on perceived safety, a three condition (light distribution: Darkspot vs. Spotlight vs. Control) repeated measures ANOVA was conducted to test statistically the differences in perceived personal safety for participant with different levels of attractiveness. The attractiveness variable was centred. Assumptions of normality and sphericity were met. Again, we found a statistically significant main effect of light distribution on perceived safety with $F(2, 98) = 14.70$, and $p<0.001$ with an $\eta^2_{partial}$ of 23%. Results revealed a second significant ($p = 0.04$) main effect of attractiveness on perceived personal safety with $F(2, 98) = 7.79$ with an $\eta^2_{partial}$ of 14%. Additionally results showed a significant ($p = 0.04$) attractiveness by light distribution moderation (interaction) effect of $F(2, 98) = 3.33$ with an $\eta^2_{partial}$ of 6.5%. This means that the effect of light distribution on perceived safety is different for people with different levels of attractiveness.

Further analysis is performed on participants with either a high or a low level of attractiveness. Two individual three condition (light distribution: Darkspot vs. Spotlight vs. Control) repeated measures ANOVA were conducted with perceived safety as a dependant variable on either participants with a high level of attractiveness (one standard deviation above average) or participant with a low level of attractiveness (one standard deviation below average). Assumptions of normality and sphericity were met. Results revealed a significant main effect of light distribution on perceived safety with $F(2, 98) = 14.34$, and $p<0.001$ with an $\eta^2_{partial}$ of 23% for participants with a high level of attractiveness, and a significant ($p = 0.032$) main effect of light distribution on perceived safety with $F(2, 98) = 3.58$, with an $\eta^2_{partial}$ of 7% for participants with a low high level of attractiveness.

This indicates that differences in light distributions have a larger effect on the perceived safety of participants with a high level of attractiveness than on participants with a low level of attractiveness.

Power

To assess the influence of power on the total effect of light distribution on perceived safety, a three condition (light distribution: Darkspot vs. Spotlight vs. Control) repeated measures ANOVA was conducted to test statistically the differences in perceived personal safety for participant with different levels of power. Results revealed a statistically significant main effect of light distribution on perceived safety with $F(2, 98) = 7.33$, and $p=0.001$ with an $\eta^2_{partial}$ of 13%. However, results did not show a significant main effect of power on perceived safety, nor a significant power by light distribution moderation (interaction) effect.

5 Discussion

In our experiment, light distribution significantly affected perceived personal safety of pedestrians in a dynamic street lighting setup. The level of safety perceived in the Darkspot condition was significantly lower compared to the level of safety perceived in the Spotlight and the Control condition. No differences were detected in the level of perceived personal safety between the Spotlight and the Control condition. Furthermore, the mediation model reveals almost complete mediation by the proximal cues Prospect, Exposure, Concealment and Escape.

These results supplement previous research indicating that road lighting, when implemented properly, can increase feelings of safety at night (Blobaum & Hunecke, 2005; Loewen et al., 1993). These studies however were performed using static road lighting instead of dynamic scenarios. Therefore the main contribution of this study is the successful implementation of dynamic road lighting in a field study with pedestrians. Comparing the levels of perceived safety experienced during the different dynamic light distributions indeed shows that light distribution effect a pedestrians perceived personal safety. Therefore *Hypothesis 1 stating: "Dynamic light distribution differences affect personal safety experienced by pedestrians"* is confirmed by the results. This makes road lighting an important environmental cue influencing levels of perceived personal safety by pedestrians.

Furthermore the results of the mediation analysis show almost complete mediation by the proximal cues Prospect, Exposure, Concealment and Escape. This means that the variation in perceived personal safety between road light distributions can be partly explained by the concepts of prospect (overview), concealment, exposure and escape (ability to flee). Evaluation of the mediation weights reveal prospect to be by far the most important environmental cue pedestrians use to judge whether a particular surrounding environment is safe or not. Exposure is the second most accountable mediator followed by the concealment and escape mediators. In other words, the difference in perceived personal safety between light conditions can in the first place be explained by the different levels of prospect and exposure experienced under different light distributions. Furthermore concealment and escape turned out to be important proximal cues as well in explaining the variation in perceived safety between light distributions, however they are inferior to prospect and exposure.

These results are consistent with Appleton's prospect and refuge theory and therefore confirm *Hypothesis 2 stating: "The differences in perceived personal safety in different light scenarios can be explained by the concepts of prospect (overview), concealment, exposure and escape (ability to flee)"*. Appelton's Prospect and Refuge theory suggests that humans prefer a place with prospect and refuge, because such places allow them to survey their surroundings from a place of protection (Appleton, 1975). This theory also explains the effect of escape possibilities on perceived personal safety by suggesting that in case of an actual attack by an assailant the victim will try to escape from its offender (Appleton, 1975). Consequently, anticipated entrapment will evoke fear, even if there is no potential offender around (Nasar et al., 1993; Nasar & Jones, 1997).

In contrast to previous research, refuge is specified in the present experiment as the two separate environmental cues exposure and concealment, because of the dual affordances of refuge (Nasar, 2000). The results justify this segmentation because both exposure and concealment turned out to be two distinct different variables affecting a person's perceived personal safety. The difference between the two is that concealment directly describes hiding possibilities for potential offenders, whereas exposure defined as the perceptibility of a pedestrian. With respect to exposure, we expected that when pedestrians are very noticeable for others they would feel less safe. We expected such a negative effect of exposure on safety, because high visibility would make it easier for a potential offender to asses whether a pedestrian would make an attractive target, and whether he or she posses the power to defend him- or herself during an attack. However this expectation was not supported by the results. In contrast, being exposed by road lighting was experienced by participants as a positive feature. The more exposed the participants were, the more perceived personal safety was experienced. A possible explanation for this preference for pedestrians to be exposed by road lighting is that being perceived by others pedestrians weighs more heavily when judging their level of safety, than the negative side effect that potential offenders can also exactly assess their level of attractiveness and power. The reasoning behind this preference to be detected by other pedestrians could be that, in case of an emergency (attack by an offender), fellow pedestrians can assist in scaring of the offender or calling the local authorities. They will not be able to do this if they do not see the incident happening due to low exposure by road lighting of the victim.

Additionally results showed a clear preference for dynamic light distributions in which the pedestrian's own location rather than his or her direct surroundings is illuminated. This is consistent with research by de Kort and colleagues on the evaluation of static light distributions (De Kort et al., 2010). This suggests that pedestrians prefer a light distribution in which their personal and action space (<30 m) is illuminated rather than their vista space (>30 m). These results thus contradict *Hypothesis 3* which states that *"pedestrians would feel safer in a light distribution which offers light in their vista space instead of in their personal and action space, because it positively influences the proximal cues Prospect, Exposure, Concealment and Escape"*. Against our expectations, illuminating, vista rather than personal and action space did not positively influence prospect, exposure, concealment and escape. A possible explanation for this antithesis could be that prospect, which describes the level of overview one has over the direct environment, is limited to a pedestrians personal and action space and therefore prospect generated in their vista space does not contribute to their assessment of feelings of safety. Prospect becomes more specific and is valued best when it is generated close to the pedestrians own location. Alternatively, it could be the case that good prospect involves, not just being able to see what lies ahead, but what is happening at the roadside as well. Due to the parallel design of road lighting which is concentrated on the street itself and not its direct surroundings, the darkspot scenario left the roadsides relatively unlit. This might create poor prospect, many places for concealment, and poor escape possibilities on both the left and right side of a person walking down the street, which in turn reduces one's perceived personal safety. This effect is illustrated by illumination pictures taken in the Darkspot and Spotlight scenarios. The darkspot scenario (Figure 4) clearly show less diffused lighting on both verges compared to the spotlight scenario (Figure 5). This interpretation of the unexpected difference between the Darkspot and spotlight scenario is thus consistent with our findings that participants in the Darkspot perceived less prospect and escape, and more concealment.

This raises an interesting question; what is the impact of illumination of the road verges on a person's perceived personal safety? Since the present study focused mainly on light directed towards the street itself, and not the road sides, the answer to this question requires future research. In fact, it might well turn out to be the case that it is more important for pedestrians' perceived personal safety to light up the verges of a street, than to illuminate the street itself outside a person's personal and action space. Road verges generally contain bushes and trees which create many concealment possibilities for possible offenders. These concealment possibilities aren't available on the street itself. Furthermore, if only the street and not the verges are lit, no prospect is generated to both the left and right side of the street. Because of this reasoning it is recommended to start future research with assessing the influence of the level of illumination present in road verges on pedestrian's perceived personal safety. A second issue which remains unclear is the range in which pedestrians benefit from light the most. In the performed study participants preferred the spotlight and control scenario over the Darkspot scenario in terms of perceived safety. Although the spotlight scenario and the control scenario differed in terms of illumination range, results did not reveal differences in perceived personal safety between the spotlight and control scenarios. As a result no guidelines can yet be deduced about the most suitable range in which pedestrians would like to be exposed to illumination in order to maximize their perceived personal safety. It is recommended to explore this issue more extensively in future research.

Results also show a substantial difference in perceived personal safety measured between men and women. The negative effect of less lighting at the pedestrians owns location is larger for women than for men. This results in less feelings of perceived personal safety for women than for men being exposed to similar lighting conditions. Women overall perceive lower levels of perceived personal safety than men. This difference can be partly explained with the social psychological model by Van der Wurff and colleagues, which indicates power and attractiveness to be important variables influencing fear of crime (van der Wurff et al., 1989). Our female participants perceived themselves as less powerful to defend themselves in case of an attack, or to lack the physical property to escape from a possible offender. Additionally, they perceived themselves as a more attractive target for assault than did our male participants. Consistent with the model by van der Wurff and colleagues, we found that pedestrians who perceived themselves to be highly attractive for a potential assault experience lower levels of personal safety. In addition, the results showed a significant moderation effect of attractiveness on the effect of light distribution on perceived personal safety. This means that for pedestrian with high levels of attractiveness (women), light distribution is more important factor necessary to feel safe, than for pedestrians who do not perceive themselves to be an attractive target. However unlike the prediction by the psychological model of van de Wurff et al. power did not affect perceived personal safety in such a way (van der Wurff et al., 1989). Recapitulating these results partly confirms hypothesis 4 stating: '*Hypothesis H4: Gender, attractiveness and power affect perceived personal safety experienced in different light distributions.* This shows that the socio demographic variables gender and attractiveness are important factors influencing the perceived personal safety of pedestrians at night.

There were several limitations to the present experiment. Testbed "de Zaale" is equipped with lamppost suitable for motorized traffic and not for pedestrians in residential areas. As a result, the lampposts are placed too far apart from one another to change light distributions on short distances close to the pedestrian. A second limitation of the performed study was that participants themselves had to indicate there position on the road, and as such had to control the light with a transmitter device. This could have given the participants a feeling of control on the light settings, which might have affected their feelings of personal safety. The third notable limitation is the private and protected character of the TU/e campus. Most of the participants rated the environment surrounding "de Zaale" as very safe. Therefore the effect of different light distributions could be very different when pedestrians feel unsafe.

Repeating the study in an environment which is perceived as less safe can result in larger differences in perceived personal safety.

Despite these limitations the present study demonstrates that the manner in which light is distributed across the poles in an intelligent dynamic road lighting setup influences the perceived personal safety of pedestrians at night. We have shown in an experimental field study that light has an effect on the proximal cues prospect, exposure, concealment and escape. Prospect is indicated to be the most important proximal cue influencing a pedestrians perceived personal safety. The relatively highest level of perceived personal safety is experienced when a pedestrian's personal and action space are sufficiently illuminated. Illuminating these areas increases prospect, exposure an escape, and decreases concealment. Additional illumination in a pedestrian's vista space does not necessarily contribute to the increase of their perceived personal safety. Furthermore individual differences between pedestrians such as gender and attractiveness can enhance the negative effect of poor illumination on perceived personal safety. This knowledge should be integrated in the future design of an intelligent dynamic road lighting system in order to maximise the personal safety of pedestrians using such a system at night.

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Appendices

Appendix A

Instructie straatverlichtingexperiment

Je gaat zo meteen 3 keer deze straat doorlopen met 3 verschillende lichtinstellingen. Ik wil je vragen om **in een rustig en constant tempo** door de straat te wandelen en tijdens de wandeling zoveel mogelijk de straat en haar omgeving in je op te nemen. **Kijk daarom niet naar de verlichtingunits maar kijk zoveel mogelijke om je heen!**
Aan het einde van de straat wordt je opgewacht door een medewerker die je een vragenlijst aanbiedt. Deze vragenlijst moet je invullen en bevat vragen over de straat en haar omgeving. Dit proces wordt nog tweemaal herhaald. Verder krijg je nog wat meetapparatuur om tijdens het wandelen, hier hoef je niet op te letten en niets mee te doen. Ook krijg je een walky talky mee met daarop een knopje met een muzieknoot. **Deze knop moet je tweemaal indrukken tijdens het lopen 5 meter voordat je de volgende lantaarnpaal passeert.**

Veel succes!

Appendix B

Deelnemer Conditie

Questionnaire 1

Vul alsjeblieft de volgende vragenlijst in. Bij elke vraag staan steeds vijf blokjes die u kunt gebruiken om antwoord te geven. Boven en naast de blokjes is een beschrijving van de antwoordmogelijkheden gegeven. Kruis steeds het antwoordblokje aan dat het beste overeenkomt met jouw beleving. Er zijn geen goede of foute antwoorden. Denk niet te lang na over de antwoorden, maar vul dat antwoord in dat het eerste in je opkomt.

		Zeer	Enigszins	Neutraal	Enigszins	Zeer	
1. Hoe veilig of onveilig voelde je je tijdens het doorlopen van de straat?	Onveilig						Veilig
2. Hoe gemakkelijk of ongemakkelijk voelde je je in deze straat?	Ongemakkelijk						Gemakkelijk
3. In welke mate zou je normaal gesproken een straat als deze vermijden of kiezen tijdens een nachtelijke wandeling?	Vermijden						Kiezen
4. Hoe goed of slecht was je overzicht over de straat?	Slecht						Goed
5. Hoe slecht of goed kon je zien wat er in de straat gebeurde?	Slecht						Goed
6. Hoe goed of slecht kon je objecten in de straat zien?	Slecht						Goed
7. Hoe zichtbaar of onzichtbaar voelde je je terwijl je door deze straat liep?	Onzichtbaar						Zichtbaar
8. Hoe goed of slecht ben je waarneembaar door andere mensen in deze straat?	Goed						Slecht
9. Hoe goed of slecht kunnen andere mensen je zien terwijl je door deze straat loopt?	Goed						Slecht
10. Hoe moeilijk of makkelijk kunnen mensen die kwaad willen zich in deze straat schuilhouden?	Makkelijk						Moeilijk
11. Waren er in deze straat veel of weinig plekken waar	Veel						Weinig

mogelijke criminelen zich zouden kunnen schuilhouden?							
12. Hoe groot of klein was is kans dat een kwaadwillend persoon zich in deze straat ongezien ophield?	Groot	☐	☐	☐	☐	☐	Klein
13. Hoe groot of klein is de kans dat je in deze straat kon vluchten in geval van nood?	Klein	☐	☐	☐	☐	☐	Groot
14. Hoe moeilijk of makkelijk kun je jezelf in deze straat in veiligheid brengen?	Moeilijk	☐	☐	☐	☐	☐	Makkelijk
15. Hoe moeilijk of makkelijk kun je in deze straat in het nauw gedreven worden door een kwaadwillend persoon?	Makkelijk	☐	☐	☐	☐	☐	Moeilijk
16. Hoe goed of slecht is de kwaliteit van de straatverlichting in deze straat?	Slecht	☐	☐	☐	☐	☐	Goed

Deelnemer	Conditie

Questionnaire 2

Wat is je leeftijd? ☐

Wat is je geslacht? ☐

		Erg	Enigszins	Neutraal	Enigszins	Erg	
17. In hoeverre beschouw je jezelf als een aantrekkelijk of onaantrekkelijk doelwit voor mogelijke criminelen?	Aantrekkelijk	☐	☐	☐	☐	☐	Onaantrekkelij
18. In hoeverre beschouw je jouw bezittingen als een aantrekkelijk of onaantrekkelijk doelwit voor mogelijke criminelen?	Aantrekkelijk	☐	☐	☐	☐	☐	Onaantrekkelij
19. Hoe groot of klein acht je de kans dat een belager jou aanvalt?	Groot	☐	☐	☐	☐	☐	Klein
20. Hoe goed of slecht acht je jezelf in staat om te ontsnappen aan een belager?	Slecht	☐	☐	☐	☐	☐	Goed
21. Hoe goed of slecht acht je jezelf in staat om een belager te verjagen?	Slecht	☐	☐	☐	☐	☐	Goed
22. Hoe goed of slecht acht je jezelf in staat om je te verdedigen bij een aanval van een belager?	Slecht	☐	☐	☐	☐	☐	Goed

23. Hoe veilig of onveilig verwacht je dat de omgeving rond deze straat is?
(kruis een antwoord aan)

Zeer onveilig	Onveilig	Een beetje onveilig	Een beetje veilig	Veilig	Zeer veilig
☐	☐	☐	☐	☐	☐

24. Hoe vaak kom je op deze straat (De Zaale) van het TU/e terrein?
(kruis een antwoord aan)

Minder dan 1x per maand	Òngeveer 1x per maand	Meerdere keren per maand	Ongeveer 1x per week	Meer dan 1x per week
☐	☐	☐	☐	☐

Appendix C

Correlations

Correlations Scenario Darkspot

	Mean Safety	Mean Prospect	Mean Exposure	Mean Concealment	Mean Escape
Mean Safety *Sig.*	1	.752 .000	.341 .015	-.545 .000	.512 .000
Mean Prospect *Sig.*	.752 .000	1	.371 .008	-.517 .000	.493 .000
Mean Exposure *Sig.*	.341 .015	.371 .008	1	-.210 .143	.138 .338
Mean Concealment *Sig.*	-.0545 .000	-.517 .000	-.210 .143	1	-.261 .067
Mean Escape *Sig.*	.512 .000	.493 .000	.138 .338	-.261 .067	1

Correlations Scenario Spotlight

	Mean Safety	Mean Prospect	Mean Exposure	Mean Concealment	Mean Escape
Mean Safety *Sig.*	1	.638 .000	.360 .010	-.426 .002	.378 .007
Mean Prospect *Sig.*	.638 .000	1	.147 .308	-.516 .000	.318 .024
Mean Exposure *Sig.*	.360 .010	.147 .308	1	-.205 .154	-.150 .915
Mean Concealment *Sig.*	-.426 .002	-.516 .000	-.205 .154	1	-.371 .008
Mean Escape *Sig.*	.378 .007	.318 .024	-.015 .915	-.371 .008	1

Correlations Scenario Control

	Mean Safety	Mean Prospect	Mean Exposure	Mean Concealment	Mean Escape
Mean Safety *Sig.*	1	.588 .000	.308 .030	-.482 .000	.528 .000
Mean Prospect *Sig.*	.588 .000	1	.403 .004	-.465 .001	.204 .155
Mean Exposure *Sig.*	.308 .030	.403 .004	1	-.214 .136	.150 .298
Mean Concealment *Sig.*	-.482 .000	-.465 .001	-.214 .136	1	-.375 .007
Mean Escape *Sig.*	.528 .000	.204 .155	.150 .298	-.2375 .007	1

Appendix D

DARKSPOT 1 T/M 12

						Pole ID						
	5.11	5.10	5.9	5.8	5.7	5.6	4.24	4.23	4.23.1	4.20.1	4.20	4.19
Location participant	OLC12	OLC11	OLC10	OLC9	OLC8	OLC7	OLC6	OLC5	OLC4	OLC3	OLC2	OLC1
5.11	1	1	1	1	1	1	1	1	1	40	1	1
	1	1	1	1	1	1	1	1	10	30	1	20
	1	1	1	1	1	1	1	1	20	20	1	40
	1	1	1	1	1	1	1	1	30	10	1	60
5.10	1	1	1	1	1	1	1	1	40	1	1	80
	1	1	1	1	1	1	1	20	30	1	1	60
	1	1	1	1	1	1	1	40	20	1	1	40
	1	1	1	1	1	1	1	60	10	1	1	20
5.9	1	1	1	1	1	1	1	80	1	1	80	1
	1	1	1	1	1	1	20	60	1	10	60	1
	1	1	1	1	1	1	40	40	1	20	40	1
	1	1	1	1	1	1	60	20	1	30	20	1
5.8	1	1	1	1	1	1	80	1	1	40	1	1
	1	1	1	1	1	20	60	1	10	30	1	1
	1	1	1	1	1	40	40	1	20	20	1	1
	1	1	1	1	1	60	20	1	30	10	1	1
5.7	1	1	1	1	1	80	1	1	40	1	1	1
	1	1	1	1	20	60	1	20	30	1	1	1
	1	1	1	1	40	40	1	40	20	1	1	1
	1	1	1	1	60	20	1	60	10	1	1	1
5.6	1	1	1	1	80	1	1	80	1	1	1	1
	1	1	1	20	60	1	20	60	1	1	1	1
	1	1	1	40	40	1	40	40	1	1	1	1

	1	1	1	60	20	1	60	20	1	1	1	1
4.24	1	1	1	80	1	1	80	1	1	1	1	1
	1	1	20	60	1	20	60	1	1	1	1	1
	1	1	40	40	1	40	40	1	1	1	1	1
	1	1	60	20	1	60	20	1	1	1	1	1
4.23	1	1	80	1	1	80	1	1	1	1	1	1
	1	20	60	1	20	60	1	1	1	1	1	1
	1	40	40	1	40	40	1	1	1	1	1	1
	1	60	20	1	60	20	1	1	1	1	1	1
4.23.1	1	80	1	1	80	1	1	1	1	1	1	1
	20	60	1	20	60	1	1	1	1	1	1	1
	40	40	1	40	40	1	1	1	1	1	1	1
	60	20	1	60	20	1	1	1	1	1	1	1
4.20.1	80	1	1	80	1	1	1	1	1	1	1	1
	60	1	20	60	1	1	1	1	1	1	1	1
	40	1	40	40	1	1	1	1	1	1	1	1
	20	1	60	20	1	1	1	1	1	1	1	1
4.20	1	1	80	1	1	1	1	1	1	1	1	1
	1	1	80	1	1	1	1	1	1	1	1	1
	1	1	80	1	1	1	1	1	1	1	1	1
	1	1	80	1	1	1	1	1	1	1	1	1
4.19	1	1	80	1	1	1	1	1	1	1	1	1

Numbers are percentages of maximum illumination.

DARKSPOT 12 T/M 1

						Pole ID						
	5.11	5.10	5.9	5.8	5.7	5.6	4.24	4.23	4.23.1	4.20.1	4.20	4.19
Location participant	OLC12	OLC11	OLC10	OLC9	OLC8	OLC7	OLC6	OLC5	OLC4	OLC3	OLC2	OLC1
5.11	1	1	80	1	1	1	1	1	1	1	1	1
	20	1	60	20	1	1	1	1	1	1	1	1
	40	1	40	40	1	1	1	1	1	1	1	1
	60	1	20	60	1	1	1	1	1	1	1	1
5.10	80	1	1	80	1	1	1	1	1	1	1	1
	60	20	1	60	20	1	1	1	1	1	1	1
	40	40	1	40	40	1	1	1	1	1	1	1
	20	60	1	20	60	1	1	1	1	1	1	1
5.9	1	80	1	1	80	1	1	1	1	1	1	1
	1	60	20	1	60	20	1	1	1	1	1	1
	1	40	40	1	40	40	1	1	1	1	1	1
	1	20	60	1	20	60	1	1	1	1	1	1
5.8	1	1	80	1	1	80	1	1	1	1	1	1
	1	1	60	20	1	60	20	1	1	1	1	1
	1	1	40	40	1	40	40	1	1	1	1	1
	1	1	20	60	1	20	60	1	1	1	1	1
5.7	1	1	1	80	1	1	80	1	1	1	1	1
	1	1	1	60	20	1	60	20	1	1	1	1
	1	1	1	40	40	1	40	40	1	1	1	1
	1	1	1	20	60	1	20	60	1	1	1	1
5.6	1	1	1	1	80	1	1	80	1	1	1	1
	1	1	1	1	60	20	1	60	10	1	1	1
	1	1	1	1	40	40	1	40	20	1	1	1
	1	1	1	1	20	60	1	20	30	1	1	1
4.24	1	1	1	1	1	80	1	1	40	1	1	1
	1	1	1	1	1	60	20	1	30	10	1	1

	1	1	1	1	1	40	40	1	20	20	1	1
	1	1	1	1	1	20	60	1	10	30	1	1
4.23	1	1	1	1	1	1	80	1	1	40	1	1
	1	1	1	1	1	1	60	20	1	30	20	1
	1	1	1	1	1	1	40	40	1	20	40	1
	1	1	1	1	1	1	20	60	1	10	60	1
4.23.1	1	1	1	1	1	1	1	80	1	1	80	1
	1	1	1	1	1	1	1	60	10	1	60	20
	1	1	1	1	1	1	1	40	20	1	40	40
	1	1	1	1	1	1	1	20	30	1	20	60
4.20.1	1	1	1	1	1	1	1	1	40	1	1	80
	1	1	1	1	1	1	1	1	30	10	30	70
	1	1	1	1	1	1	1	1	20	20	20	60
	1	1	1	1	1	1	1	1	10	30	10	50
4.20	1	1	1	1	1	1	1	1	1	40	1	1
	1	1	1	1	1	1	1	1	1	40	1	1
	1	1	1	1	1	1	1	1	1	40	1	1
	1	1	1	1	1	1	1	1	1	40	1	1
4.19	1	1	1	1	1	1	1	1	1	40	1	1

Numbers are percentages of maximum illumination.

						Pole ID						
Location participant	5.11	5.10	5.9	5.8	5.7	5.6	4.24	4.23	4.23.1	4.20.1	4.20	4.19
5.11	OLC12	OLC11	OLC10	OLC9	OLC8	OLC7	OLC6	OLC5	OLC4	OLC3	OLC2	OLC1
	1	1	1	1	1	1	1	1	1	1	80	80
	1	1	1	1	1	1	1	1	1	10	80	60
	1	1	1	1	1	1	1	1	1	20	80	40
5.10	1	1	1	1	1	1	1	1	1	30	80	20
	1	1	1	1	1	1	1	1	1	40	80	1
	1	1	1	1	1	1	1	1	10	40	60	1
	1	1	1	1	1	1	1	1	20	40	40	1
5.9	1	1	1	1	1	1	1	1	30	40	20	1
	1	1	1	1	1	1	1	1	40	40	1	1
	1	1	1	1	1	1	1	20	40	30	1	1
	1	1	1	1	1	1	1	40	40	20	1	1
5.8	1	1	1	1	1	1	1	60	40	10	1	1
	1	1	1	1	1	1	1	80	40	1	1	1
	1	1	1	1	1	1	20	80	30	1	1	1
	1	1	1	1	1	1	40	80	20	1	1	1
5.7	1	1	1	1	1	1	60	80	10	1	1	1
	1	1	1	1	1	1	80	80	1	1	1	1
	1	1	1	1	1	20	80	60	1	1	1	1
	1	1	1	1	1	40	80	40	1	1	1	1
5.6	1	1	1	1	1	60	80	20	1	1	1	1
	1	1	1	1	1	80	80	1	1	1	1	1
	1	1	1	1	20	80	60	1	1	1	1	1
	1	1	1	1	40	80	40	1	1	1	1	1
4.24	1	1	1	1	60	80	20	1	1	1	1	1
	1	1	1	1	80	80	1	1	1	1	1	1
	1	1	1	20	80	60	1	1	1	1	1	1

	1	1	1	40	80	40	1	1	1	1	1	1
4.23	1	1	1	60	80	20	1	1	1	1	1	1
	1	1	1	80	80	1	1	1	1	1	1	1
	1	1	20	80	60	1	1	1	1	1	1	1
	1	1	40	80	40	1	1	1	1	1	1	1
4.23.1	1	1	60	80	20	1	1	1	1	1	1	1
	1	1	80	80	1	1	1	1	1	1	1	1
	1	20	80	60	1	1	1	1	1	1	1	1
	1	40	80	40	1	1	1	1	1	1	1	1
4.20.1	1	60	80	20	1	1	1	1	1	1	1	1
	1	80	80	1	1	1	1	1	1	1	1	1
	20	80	60	1	1	1	1	1	1	1	1	1
	40	80	40	1	1	1	1	1	1	1	1	1
4.20	60	80	20	1	1	1	1	1	1	1	1	1
	80	80	1	1	1	1	1	1	1	1	1	1
	80	80	1	1	1	1	1	1	1	1	1	1
	80	80	1	1	1	1	1	1	1	1	1	1
4.19	80	80	1	1	1	1	1	1	1	1	1	1
	80	80	1	1	1	1	1	1	1	1	1	1

SPOTLIGHT 12 T/M 1

	Pole ID											
	5.11	5.10	5.9	5.8	5.7	5.6	4.24	4.23	4.23.1	4.20.1	4.20	4.19
Location participant	OLC12	OLC11	OLC10	OLC9	OLC8	OLC7	OLC6	OLC5	OLC4	OLC3	OLC2	OLC1
5.11	80	80	1	1	1	1	1	1	1	1	1	1
	60	80	20	1	1	1	1	1	1	1	1	1
	40	80	40	1	1	1	1	1	1	1	1	1
	20	80	60	1	1	1	1	1	1	1	1	1
5.10	1	80	80	1	1	1	1	1	1	1	1	1
	1	60	80	20	1	1	1	1	1	1	1	1
	1	40	80	40	1	1	1	1	1	1	1	1
	1	20	80	60	1	1	1	1	1	1	1	1
5.9	1	1	80	80	1	1	1	1	1	1	1	1
	1	1	60	80	20	1	1	1	1	1	1	1
	1	1	40	80	40	1	1	1	1	1	1	1
	1	1	20	80	60	1	1	1	1	1	1	1
5.8	1	1	1	80	80	1	1	1	1	1	1	1
	1	1	1	60	80	20	1	1	1	1	1	1
	1	1	1	40	80	40	1	1	1	1	1	1
	1	1	1	20	80	60	1	1	1	1	1	1
5.7	1	1	1	1	80	80	1	1	1	1	1	1
	1	1	1	1	60	80	20	1	1	1	1	1
	1	1	1	1	40	80	40	1	1	1	1	1
	1	1	1	1	20	80	60	1	1	1	1	1
5.6	1	1	1	1	1	80	80	1	1	1	1	1
	1	1	1	1	1	60	80	20	1	1	1	1
	1	1	1	1	1	40	80	40	1	1	1	1
	1	1	1	1	1	20	80	60	1	1	1	1
4.24	1	1	1	1	1	1	80	80	1	1	1	1
	1	1	1	1	1	1	60	80	10	1	1	1

	1	1	1	1	1	1	40	80	20	1	1	1
	1	1	1	1	1	1	20	80	30	1	1	1
4.23	1	1	1	1	1	1	1	80	40	1	1	1
	1	1	1	1	1	1	1	60	40	10	1	1
	1	1	1	1	1	1	1	40	40	20	1	1
	1	1	1	1	1	1	1	20	40	30	1	1
4.23.1	1	1	1	1	1	1	1	1	40	40	1	1
	1	1	1	1	1	1	1	1	30	40	20	1
	1	1	1	1	1	1	1	1	20	40	40	1
	1	1	1	1	1	1	1	1	10	40	60	1
4.20.1	1	1	1	1	1	1	1	1	1	40	80	1
	1	1	1	1	1	1	1	1	1	30	80	20
	1	1	1	1	1	1	1	1	1	20	80	40
	1	1	1	1	1	1	1	1	1	10	80	80
4.20	1	1	1	1	1	1	1	1	1	1	80	80
	1	1	1	1	1	1	1	1	1	1	80	80
	1	1	1	1	1	1	1	1	1	1	80	80
	1	1	1	1	1	1	1	1	1	1	80	80
4.19	1	1	1	1	1	1	1	1	1	1	80	80

CONTROL 1 T/M 12

						Pole ID						
	5.11	5.10	5.9	5.8	5.7	5.6	4.24	4.23	4.23.1	4.20.1	4.20	4.19
Location participant	OLC12	OLC11	OLC10	OLC9	OLC8	OLC7	OLC6	OLC5	OLC4	OLC3	OLC2	OLC1
5.11	1	1	1	1	1	1	1	1	1	1	54	54
	1	1	1	1	1	1	1	1	1	7	54	54
	1	1	1	1	1	1	1	1	1	13	54	54
	1	1	1	1	1	1	1	1	1	20	54	54
5.10	1	1	1	1	1	1	1	1	1	27	54	54
	1	1	1	1	1	1	1	1	7	27	54	38
	1	1	1	1	1	1	1	1	13	27	54	22
	1	1	1	1	1	1	1	1	20	27	54	11
5.9	1	1	1	1	1	1	1	1	27	27	54	1
	1	1	1	1	1	1	1	11	27	27	38	1
	1	1	1	1	1	1	1	22	27	27	22	1
	1	1	1	1	1	1	1	38	27	27	11	1
5.8	1	1	1	1	1	1	1	54	27	27	1	1
	1	1	1	1	1	1	11	54	27	20	1	1
	1	1	1	1	1	1	22	54	27	13	1	1
	1	1	1	1	1	1	38	54	27	7	1	1
5.7	1	1	1	1	1	1	54	54	27	1	1	1
	1	1	1	1	1	11	54	54	20	1	1	1
	1	1	1	1	1	22	54	54	13	1	1	1
	1	1	1	1	1	38	54	54	7	1	1	1
5.6	1	1	1	1	1	54	54	54	1	1	1	1
	1	1	1	1	11	54	54	38	1	1	1	1
	1	1	1	1	22	54	54	22	1	1	1	1
	1	1	1	1	38	54	54	11	1	1	1	1
4.24	1	1	1	1	54	54	54	1	1	1	1	1

	1	1	1	11	54	54	38	1	1	1	1	1
	1	1	1	22	54	54	22	1	1	1	1	1
	1	1	1	38	54	54	11	1	1	1	1	1
4.23	1	1	1	54	54	54	1	1	1	1	1	1
	1	1	11	54	54	38	1	1	1	1	1	1
	1	1	22	54	54	22	1	1	1	1	1	1
	1	1	38	54	54	11	1	1	1	1	1	1
4.23.1	1	1	54	54	54	1	1	1	1	1	1	1
	1	11	54	54	38	1	1	1	1	1	1	1
	1	22	54	54	22	1	1	1	1	1	1	1
	1	38	54	54	11	1	1	1	1	1	1	1
4.20.1	1	54	54	54	7	1	1	1	1	1	1	1
	11	54	54	38	1	1	1	1	1	1	1	1
	22	54	54	22	1	1	1	1	1	1	1	1
	38	54	54	11	1	1	1	1	1	1	1	1
4.20	54	54	54	1	1	1	1	1	1	1	1	1
	54	54	38	1	1	1	1	1	1	1	1	1
	54	54	22	1	1	1	1	1	1	1	1	1
	54	54	11	1	1	1	1	1	1	1	1	1
4.19	54	54	1	1	1	1	1	1	1	1	1	1

CONTROL 12 T/M 1

	Pole ID											
	5.11	5.10	5.9	5.8	5.7	5.6	4.24	4.23	4.23.1	4.20.1	4.20	4.19
Location participant	OLC12	OLC11	OLC10	OLC9	OLC8	OLC7	OLC6	OLC5	OLC4	OLC3	OLC2	OLC1
5.11	54	54	1	1	1	1	1	1	1	1	1	1
	54	54	11	1	1	1	1	1	1	1	1	1
	54	54	22	1	1	1	1	1	1	1	1	1
	54	54	38	1	1	1	1	1	1	1	1	1
5.10	54	54	54	1	1	1	1	1	1	1	1	1
	38	54	54	11	1	1	1	1	1	1	1	1
	22	54	54	22	1	1	1	1	1	1	1	1
	11	54	54	38	1	1	1	1	1	1	1	1
5.9	1	54	54	54	1	1	1	1	1	1	1	1
	1	38	54	54	11	1	1	1	1	1	1	1
	1	22	54	54	22	1	1	1	1	1	1	1
	1	11	54	54	38	1	1	1	1	1	1	1
5.8	1	1	54	54	54	1	1	1	1	1	1	1
	1	1	38	54	54	11	1	1	1	1	1	1
	1	1	22	54	54	22	1	1	1	1	1	1
	1	1	11	54	54	38	1	1	1	1	1	1
5.7	1	1	1	54	54	54	1	1	1	1	1	1
	1	1	1	38	54	54	11	1	1	1	1	1
	1	1	1	22	54	54	22	1	1	1	1	1
	1	1	1	11	54	54	38	1	1	1	1	1
5.6	1	1	1	1	54	54	54	1	1	1	1	1
	1	1	1	1	38	54	54	11	1	1	1	1
	1	1	1	1	22	54	54	22	1	1	1	1
	1	1	1	1	11	54	54	38	1	1	1	1
4.24	1	1	1	1	1	54	54	54	1	1	1	1

	1	1	1	1	1	38	54	54	7	1	1	1
	1	1	1	1	1	22	54	54	13	1	1	1
	1	1	1	1	1	11	54	54	20	1	1	1
4.23	1	1	1	1	1	1	54	54	27	1	1	1
	1	1	1	1	1	1	38	54	27	7	1	1
	1	1	1	1	1	1	22	54	27	13	1	1
	1	1	1	1	1	1	11	54	27	20	1	1
4.23.1	1	1	1	1	1	1	1	54	27	27	1	1
	1	1	1	1	1	1	1	38	27	27	11	1
	1	1	1	1	1	1	1	22	27	27	22	1
	1	1	1	1	1	1	1	11	27	27	38	1
4.20.1	1	1	1	1	1	1	1	1	27	27	54	1
	1	1	1	1	1	1	1	1	20	27	54	11
	1	1	1	1	1	1	1	1	13	27	54	22
	1	1	1	1	1	1	1	1	7	27	54	38
4.20	1	1	1	1	1	1	1	1	1	27	54	54
	1	1	1	1	1	1	1	1	1	20	54	54
	1	1	1	1	1	1	1	1	1	13	54	54
	1	1	1	1	1	1	1	1	1	7	54	54
4.19	1	1	1	1	1	1	1	1	1	1	54	54