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Illuminating for Safety: Investigating the Role of Lighting Appraisals on the Perception of Safety in the Urban Environment

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Abstract

In two studies, we took a prospect–refuge based perspective to investigate how lighting and other physical attributes (i.e., prospect, concealment, and entrapment) affect people's judgments of the safety of urban streets during nighttime. Both studies complement existing research, which predominantly use factorial designs, with more ecologically valid correlational research using a large and representative sample of urban streets as stimulus materials. Results from Study 1 corroborate existing research demonstrating that differences in prospect, concealment, and entrapment predicted, to a large extent, variation in the perceived safety of urban streets—thus demonstrating the utility of such environmental information for making safety judgments in real-life settings. Results from a mediation analysis conducted in Study 2 showed that the relation between appraisals of lighting quality and safety judgments was completely accounted for by co-occurring variation in appraisals of prospect and entrapment. Implications for theory and methodology are discussed.

Keywords

urban environments, environmental perception, safety perceptions, lighting, prospect–refuge theory

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Introduction

Street lighting has become a ubiquitous part of modern society. In a relatively short amount of time, street lighting has managed to pervade the daily life of virtually every inhabitant of the world's urbanized regions, up to the point where it often may no longer be an explicit part of conscious experience—noticed only when it is not present or not working properly. One of the central ideas underlying this proliferation of street lighting is that better or more lighting is both negatively related to the incidence of crime and positively related to subjective experiences of safety. Indeed, amid the myriad of potential measures, installing or improving street lighting remains one of the most often used strategies aimed at (re)designing urban environments in such a way as to reduce the incidence of crime and, ultimately, to improve feelings of safety in public space (Cozens, Saville, & Hillier, 2005; Crowe, 2000).

While the empirical evidence for an effect of lighting on the incidence of crime is still mixed (e.g., Marchant, 2004, 2010; Pease, 1999; Welsh & Farrington, 2008), there is little debate in the literature about the positive effect of street lighting on subjective experiences of safety (e.g., Fotios, Unwin, & Farrall, 2015; Lorenc et al., 2013; Welsh & Farrington, 2008). A unique characteristic of light is that it determines the visibility of objects and people in the immediate environment. Based on a review of the literature, Boyce and Gutkowski (1995) suggested that the major factor mediating the effect of lighting on crime and safety perception is the extent to which people are able to perform long-range detection of possible threats and make confident facial recognitions of other people on the street (see also Caminada & Van Bommel, 1980). Painter (1994) listed altered public perceptions and increased street usage, as well as related changes in social dynamics (e.g., changes in informal surveillance or in community pride and cohesion; Pease, 1999), among the possible ways in which street lighting improvements could affect crime and safety perceptions. In addition, there may exist an intuitive or learned association between lighting and safety, such that the mere presence of lighting may directly affect people's perception of the safety of an environment. Indeed, a number of studies show that if we ask people to think about the most important environmental feature that affects their sense of safety, they more frequently mention the presence of lighting than, for example, the presence of other people or having an open view (e.g., Fotios et al., 2015; Loewen, Steel, & Suedfeld, 1993; Nasar, Fisher, & Grannis, 1993; Nasar & Jones, 1997).

A Prospect–Refuge Perspective on the Role of Lighting

Another line of research has adopted Appleton's (1975) prospect–refuge theory to understand how safety-related environmental characteristics, including lighting, affect people's sense of safety (e.g., Blöbaum & Hunecke, 2005; Boomsma & Steg, 2014; Fisher & Nasar, 1992; Loewen et al., 1993; Nasar & Bokharaei, 2017a, 2017b). In short, prospect–refuge theory asserts that in most species, the satisfaction of basic needs is dependent on a combination of the ability to see (i.e., prospect) and the ability to hide (i.e., refuge), and that environmental preference is shaped according to the extent that environments offer these kind of opportunities (Appleton, 1975, 1984).

Adopting Appleton's prospect–refuge model, researchers have subsequently identified three important cues that people use to determine the safety of an environment: *prospect*, *concealment*, and *entrapment* (e.g., Fisher & Nasar, 1992; Nasar et al., 1993). Prospect is typically defined as the extent to which the physical features of an environment allow an unobstructed field of view over the environment. In contrast, concealment refers to the extent to which an environment offers hiding spots for potential offenders (e.g., bushes and walls, but shadows as well). Finally, entrapment refers to the extent to which physical features of the environment impose a physical barrier to escape in case of an emergency (Nasar & Jones, 1997).

The notion that these safety-related environmental characteristics (i.e., prospect, concealment, and entrapment) are important determinants of safety perceptions has received ample support from studies showing that environments offering relatively high levels of prospect and low levels of concealment and entrapment tend to be associated with lower levels of reported fear of crime (e.g., Fisher & Nasar, 1992; Nasar et al., 1993; Nasar & Jones, 1997) and perceived danger (Blöbaum & Hunecke, 2005), and higher levels of perceived safety (Boomsma & Steg, 2014; Haans & de Kort, 2012; van Rijswijk, Rooks, & Haans, 2016).

From this prospect–refuge perspective, lighting, regarded as a feature of the immediate (or proximate) environment, may affect the perception of the safety of an environment in two different ways. On one hand, the presence of lighting may be a safety cue in and of itself, the mere presence of which may increase safety perceptions. On the other hand, lighting may exert an indirect influence on perceived safety through its impact on the other safety-related environmental characteristics (see also Boyce & Gutkowski, 1995). For example, proper lighting provides visibility and may thus positively affect prospect (e.g., Loewen et al., 1993) and negatively affect concealment (e.g., more light implies fewer possibilities to hide for potential offenders). In contrast, poor lighting may reduce prospect (e.g., due to glare), hamper visibility of escape routes, and cause dark spots in which people can hide (Nasar & Jones, 1997).

To date, several studies have investigated the effect of lighting from a prospect–refuge perspective (e.g., Blöbaum & Hunecke, 2005; Boomsma &

Steg, 2014; Loewen et al., 1993; Nasar & Bokharaei, 2017a, 2017b). Loewen and colleagues (1993), for example, found light to be the most important factor, and reported that the effect of prospect and entrapment on perceived safety was less pronounced in nighttime as compared to daytime environments. In contrast, Blöbaum and Hunecke (2005), considering solely nighttime environments, found entrapment to be the most important determinant of perceived safety. However, they did identify a similar interaction between lighting and entrapment, with entrapment having a less pronounced effect under insufficient lighting conditions. Based on these and other findings, Blöbaum and Hunecke argue that improving lighting may not be the best strategy for increasing the sense of safety in urban settings that are high in entrapment.

Although these studies have been instrumental to our current understanding of how characteristics of the physical environment (including lighting) affect safety perceptions, there are a number of methodological considerations to be made. These considerations may not only explain some of the inconsistencies across studies but also call into question the ecological validity of research findings, and thus the generalization of these findings to real-world situations and applications.

The Limitations of Current Approaches

Prospect–refuge theory is centered on the functionalist assumption that cue utilization is highly adapted to the situations that an organism encounters on a day-to-day basis (i.e., its ecological environment; also van Rijswijk et al., 2016). Consequently, if our aim is to understand how people use environmental information related to lighting, prospect, concealment, and entrapment in real-life situations—and thus to quantify the utility potential of these different cues by means of some effect size—then one should take into account the availability of such cues in the various urban settings that make up a person's ecological environment. However, many of the studies applying a prospect–refuge perspective have relied on factorial designs in which participants rate the safety of a selection of settings that differ systematically in such variables as illumination levels, prospect, concealment, and entrapment. In these (quasi-)experimental studies, the stimulus materials either consist of settings that are carefully selected based on evaluations by (expert) judges (e.g., Blöbaum & Hunecke, 2005; Fisher & Nasar, 1992; Loewen et al., 1993) or consist of systematically manipulated, mostly simulated scenes (e.g., Boomsma & Steg, 2014; Nasar & Bokharaei, 2017a, 2017b). Although such systematic factorial approaches certainly have their merits (e.g., in determining causal relations between physical attributes and safety perceptions), they also have several drawbacks that reduce ecological validity and, thus, hamper generalization of research findings to real-world situations.

First, the results of studies employing factorial approaches are influenced by the intervals of the factors in the design. For example, given that Loewen and colleagues (1993) compared the effect of daytime versus nighttime scenes (i.e., a large interval in light level) with potentially less significant intervals in the levels of prospect and entrapment, it is perhaps not very surprising that their results identified light as the most important factor influencing perceived safety. Ideally, the selected interval of a factor should resemble closely the typical values of that variable in the ecological environment. If not, then we are at risk of over- or underestimating its effect on safety perceptions. As a result, the utility potential of a certain cue in the formation of safety perceptions in real-life situations remains unclear. Fortunately, researchers typically take great care in ensuring that the selected interval of a factor remains within reasonable and practical ranges. For example, when systematically manipulating entrapment—by varying the width of streets—in a set of simulated scenes, Boomsma and Steg (2014) considered the widths of typical streets in the city in which the study was conducted. Similarly, when manipulating lighting, they considered light levels that were just below or above existing lighting recommendations. Nevertheless, it often remains difficult to select appropriate factor levels. For example, recommended lighting levels differ substantially depending on the type of pedestrian area, and may be much smaller for narrow as compared with wide streets, especially because the latter are typically used more extensively and by a more varying group of street users.

Second, in interpreting the results of studies employing a factorial design, researchers have typically assumed that lighting, prospect, concealment, and entrapment can be independently manipulated. However, these characteristics tend to covary in the urban settings that make up our ecological environment. Appraisals of prospect, for example, are found to correlate strongly with appraisals of both concealment and entrapment (van Rijswijk et al., 2016). Similarly, and as discussed above, good quality lighting is expected to be associated with better prospect, and fewer opportunities for concealment and entrapment. These naturally occurring correlations are typically ignored in studies involving factorial designs in which cues such as lighting, prospect, concealment, and entrapment are considered as independent factors. This artificial untying of variables (Brunswik, 1956) poses a threat to the interpretation of any main and interaction effects found in these studies. This is particularly the case for quasi-experimental research in which stimulus materials are selected from existing environments on the basis of ratings by judges (e.g., Blöbaum & Hunecke, 2005; Loewen et al., 1993). It is less of an issue for experimental studies, as the systematic manipulation of the factors in the design allows for orthogonality of predictor variables. However, the manipulation of such cues as prospect, concealment, and entrapment poses a different challenge. One must be cautious with interpreting a manipulation in, for example, the width of a street as a manipulation of entrapment (see, for example, Boomsma & Steg, 2014). Entrapment may result from a combination of many different variables besides the width of the street, and may also depend on variation in one of the other factors in the experimental design, such as lighting.

Third, the set of scenes that is used as stimulus material is typically only a small and nonrepresentative sample of the environments that people encounter on a day-to-day basis. For example, from the study by Fisher and Nasar (1992, see Figure 3, p. 44), it is immediately clear that it may be difficult to find, for example, urban settings that are high in concealment and high in prospect. Yet, the factorial design may dictate that such a rarely encountered setting is nonetheless included in the stimulus set. As a result, the stimulus materials used may not reflect what is typical for the ecological environment.

Taken together, these three drawbacks of factorial studies illustrate that the systematic variation of physical cues, such as lighting, prospect, concealment, and entrapment, cannot recreate the ecological environment (Brunswik, 1955, 1956). Instead, one creates at best a much contrived and study-specific version of it (see also Wicker, 1979). As a result, research findings may not be optimally informative about how people actually use proximate cues in the environment when forming a judgment of the safety of that environment.

To increase the ecological validity of current findings, existing systematic research needs to be complemented with correlational studies that use a representative set of environments as stimulus material. A stimulus set is representative when the environments in the set are similar to the participants' ecological environment with respect to the variety in and typicality of the configurations of environmental characteristics, and thus to the naturally occurring variance in and covariation between these characteristics. This requires that we extend the range of environments that we consider in our studies, and ideally so by means of random sampling procedures (e.g., Brunswik, 1955, 1956; also van Rijswijk et al., 2016). Just as we are accustomed to draw a random sample of the population to which we want to generalize our findings, we should also randomly sample the environments that we include in our stimulus set if we want to generalize findings to real-world situations. Correlational studies, however, remain rare; especially in comparison with the number of studies employing factorial designs (but see Nasar et al., 1993). Even rarer, to our knowledge, are studies that have used a large and representative set of stimulus materials (but see van Rijswijk et al., 2016).

Moreover, we need to take into account the potential effect that lighting may have on other environmental characteristics. Unfortunately, studies investigating how lighting affects appraisals of prospect, concealment, and entrapment remain rare. Preliminary evidence is provided by Haans and de Kort (2012). In their experiment, they manipulated the distribution of light across lampposts on a test street, and found changes in lighting to have a causal effect on all three environmental characteristics. Moreover, their experiment provides evidence for an indirect effect of lighting by showing that the effect of lighting on perceived safety is mediated, at least partially, by changes in an environment's prospect, concealment, and entrapment (Haans & de Kort, 2012).

Research Aims

In the current article, we investigate how appraisals of safety-related environmental characteristics (i.e., lighting, prospect, concealment, and entrapment) affect people's judgment of environmental safety using a large and representative sample of nocturnal urban scenes. As such, we are primarily interested in how site-specific physical information (i.e., proximate environmental information; see Nasar et al., 1993) is used to make a perceptual judgment of the safety of an environment. This focus thus excludes more large-scale situational influences such as prior experiences or information gathered from the media (i.e., distal determinants of safety). Furthermore, although we acknowledge the important role that social factors may play in the proximate environment when making a safety appraisal (e.g., Foster, Giles-Corti, & Knuiman, 2010; Warr, 1990), our focus also excludes the visual presence of other people and centers on the immediately apparent physical information in an environment. Thus, here, we define *perceived environmental safety* as the perceptual judgment of the safety of an environment using site-specific, immediate, and safety-related physical information from that environment.

In Study 1, we test the robustness of the prospect–refuge approach to understanding environmental safety perceptions by examining the interrelationships between appraisals of prospect, concealment, entrapment, and perceptions of environmental safety. In Study 2, we extend the findings from Study 1 by exploring the role of appraisals of lighting as they relate to appraisals of (safety-related) environmental characteristics. In particular, we test whether the relation between perceived lighting quality and perceived environmental safety is mediated by co-occurring variation in prospect, concealment, and entrapment.

Study 1

The aim of this study was to examine the relationships between the safety-related characteristics (i.e., prospect, concealment, and escape) and perceptions of environmental safety as they occur in a large sample of representative environments. In other words, the aim is to see how these variables correlate in our ecological environment. Based on the findings from the literature (e.g., Fisher & Nasar, 1992; Nasar et al., 1993), we expect appraisals of prospect to be positively associated with perceived environmental safety, and appraisals of concealment and entrapment to be negatively associated with perceived environmental safety. Using regression analysis, we test the extent to which the three environmental characteristics are predictive for perceived environmental safety in the participants' ecological environment and, thus, the extent to which the three cues have utility for pedestrians when making a safety judgment. However, in line with van Rijswijk and colleagues (2016), we also expect to find strong correlations between prospect, concealment, and entrapment in the ecological environment.

Method

Participants and design. We employed a within-subjects design in which participants evaluated a set of 100 photographs depicting nocturnal urban environments on perceived environmental safety and on prospect, concealment, and entrapment. Our sample comprised 31 participants (15 males and 16 females, M_{age} = 53.03, SD_{age} = 18.45, age range = 21-78 years). Participants were registered in the JF Schouten participant database at Eindhoven University of Technology, Eindhoven, The Netherlands, and responded to an invitation to participate in our study. None of the participants lived in Best, but four lived in Geldrop (see "Materials" section). Participants required approximately 1 hr to complete our study and received €10 as compensation for their participation.

To avoid spurious correlations between the appraisals of the three environmental characteristics on the one hand, and perceived environmental safety on the other (e.g., due to common method bias; for example, Campbell & Fiske, 1959), participants were randomly assigned to one of two groups. The first group of n = 15 participants (six males and nine females, M_{age} = 48.00, SD_{age} = 22.68, age range = 21-78 years) evaluated each photo on perceived environmental safety, while the second group of n = 16 participants (nine males and seven females, M_{age} = 58.07, SD_{age} = 11.68, age range = 27-75 years) responded to the questions of the prospect, concealment, and entrapment measures.

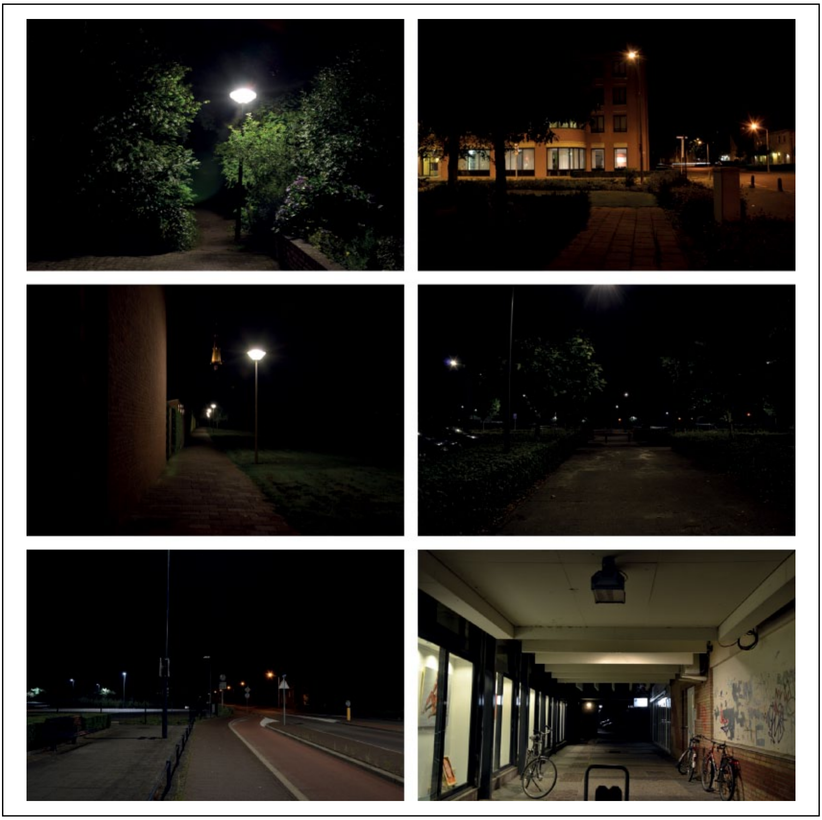

Figure 1. Examples from our set of 100 photographs of nocturnal urban environments.
Note. Original images were shown in full color.

Materials and measures. The stimulus set used in the current study comprised 100 high-resolution photographs of nocturnal urban environments that were shot in the summer of 2011 between 4:00 a.m. and 6:00 a.m. in the small towns of Best and Geldrop in the Netherlands (also van Rijswijk et al., 2016). Weather conditions during these 2 days were fair. The set of photographs sampled environments that urban residents encounter on a daily basis, but were devoid of other people or animals (see Figure 1 for some examples of the type of environments represented in our stimulus set). Decisions on which sites were selected to be photographed were made during a walk through each of the small towns. The walk itself did not follow a predefined route, but covered anything from main streets to footpaths and back alleys. A Nikon D3100 photo camera mounted on a tripod was used to shoot the photographs. All photographs were shot without flash in 14.2 megapixels (4608 × 3072 pixels; ISO 200; f/9 or f/13 depending on the assessment of the photographer; exposure time was set to automatic). There was no additional software editing of the photographs before use in the experiments. The full set of stimuli can be downloaded from http://www.antalhaans.nl/files/stimulidata.zip. The .zip file also contains the data from both studies presented in this article.

We measured perceived environmental safety and appraisals of the safety-related environmental characteristics using slight adaptations of the items used by Haans and de Kort (2012). Perceived environmental safety, prospect, concealment, and entrapment were each measured using three 5-point response format items (e.g., "How safe or unsafe do you judge this environment?"), ranging, for example, from 1 (*very unsafe*) through 3 (*neither unsafe/nor safe*) to 5 (*very safe*). For a complete overview of the items used, see Online Appendix A. We calculated the average of the three items for each measure and used these aggregate scores in our analyses ($\alpha_{\text{environmental safety}}$ = .91, α_{prospect} = .95, $\alpha_{\text{concealment}}$ = .69, $\alpha_{\text{entrapment}}$ = .79).

Procedure. The participant was welcomed into the lab, instructed to complete an informed consent form, and directed to one of eight cubicles by the experiment leader. The light was switched on in the cubicles (E_v = 25 lux on the wall at eye height, E_h = 32 lux at desk height). The participant was seated behind a desk, at approximately 50 cm in front of a 19″ color calibrated LCD monitor running at a 1600 pixels by 1200 pixels resolution and a 60 Hz refresh rate. Instructions for the participant were printed on the monitor screen, and after reading the instructions, the participant viewed a total of 100 stimuli from our photoset in random order.

The participant was instructed to imagine walking alone at night through the depicted environments. For each stimulus, a full-screen version of the stimulus was presented on the monitor screen for 5 s, after which the participant either completed the perceived environmental safety measure, or the prospect, concealment, and entrapment measures. While the participant answered these questions, a smaller version of the presented photograph was still present on the screen.

Results and Discussion

All of the reported analyses are performed on the aggregate measure scores for each of the 100 environments across all participants (see Table 1 for descriptives). We first examined the correlations among the measures of the

Table 1. Descriptives for the Measures of Environmental Safety, Prospect, Concealment, and Entrapment in Study 1 and of Perceived Quality of the Lighting in Study 2.

	M	*SD*	Minimum	Maximum
Safety	3.16	.70	1.25	4.31
Prospect	2.84	.71	1.25	4.22
Concealment	3.12	.55	1.98	4.56
Entrapment	3.23	.63	2.04	4.87
Lighting quality	2.91	.69	1.26	4.53

Note. All measurement scales ranged from 1 to 5.

Table 2. Correlations Between Measures of Environmental Safety, Prospect, Concealment, and Entrapment in Study 1 and the Measure of Perceived Quality of the Lighting in Study 2.

	Safety	Prospect	Concealment	Entrapment
Safety	—			
Prospect	.71***	—		
Concealment	−.65***	−.83***	—	
Entrapment	−.85***	−.73***	.73***	—
Lighting quality	.47***	.76***	−.48***	−.49***

***$p < .001$.

safety-related characteristics (see Table 2). Prospect was negatively correlated with concealment ($r = -.83$, $p < .001$) and entrapment ($r = -.73$, $p < .001$), and concealment was positively correlated with entrapment ($r = .73$, $p < .001$). In line with van Rijswijk and colleagues (2016), these findings indicate that prospect, concealment, and entrapment are highly correlated in our ecological environment.

Next, we examined correlations between environmental safety and the safety-related environmental characteristics (see Table 2). As expected, perceived environmental safety was positively correlated with prospect ($r = .71$, $p < .001$), and negatively correlated with concealment ($r = -.65$, $p < .001$) and entrapment ($r = -.85$, $p < .001$). These results show that appraisals of prospect, concealment, and entrapment are highly associated with the perception of environmental safety—even when ratings of perceived environmental safety and the safety-related environmental characteristics are obtained independently from each other.

Next, we used multiple regression analysis to test whether appraisals of the safety-related environmental characteristics predicted appraisals of environmental safety. We found that the three predictors accounted for approximately 75% of the variance in perceived environmental safety with $F(3, 96) = 94.77$, $p < .001$, $R^2 = .75$, and $R^2_{\text{adjusted}} = .74$. As expected, appraisals of both entrapment and prospect significantly predicted perceived environmental safety (see Table 3). Concealment was not found to predict perceived environmental safety to a significant extent (see Table 3).

One problem with multiple regression analyses is that they fail to appropriately partition the variance when the predictors in the model are highly correlated (e.g., Darlington, 1968; Graham, 2003; Tonidandel & LeBreton, 2011). Thus, an assessment of the relative contribution of the three predictors to environmental safety appraisals was impeded by the high multicollinearity between these predictor variables in our data (see Table 2). Hence, we employed the *rego* package (available for Stata at http://www.uni-leipzig.de/~rego/) that utilizes Shapley value decomposition (Stufken, 1992) to decompose the overall model goodness-of-fit index (in our case, R^2) into independent contributions of the predictor variables (Huettner & Sunder, 2012). While appraisals of concealment were not found to significantly predict appraisals of environmental safety in our multiple regression analysis, the results from the R^2 decomposition revealed that appraisals of concealment contributed only slightly less to the overall variance as compared with appraisals of prospect (see right-hand side of Table 3). In line with the multiple regression analysis, the results of the R^2 decomposition indicated that of the three predictors in our model, appraisals of entrapment contributed most strongly to the overall variance. These findings are in line with previous findings indicating that for nighttime environments, appraisals of entrapment are most strongly associated with perceived environmental safety (Blöbaum & Hunecke, 2005).

We tested the robustness of our regression model by performing 100 split sample validations. In each instance, the original 100 stimuli were randomly assigned to two groups of equal size. The regression weights of prospect, concealment, and entrapment obtained from a multiple regression analysis on the first group were then used to calculate predicted scores for perceived environmental safety of the second group. In the last step, the correlation between the observed scores and the predicted scores for the second group was calculated. The results show a high robustness of our regression model across the 100 split sample validations ($M_r = 0.86$, $SD_r = .033$, $M_{R^2} = .74$). Appraisals of prospect, concealment, and entrapment, thus, robustly accounted for approximately 75% of the variance in the perceived safety of the environments included in our stimulus set. Given our large and

Table 3. OLS Multiple Regression Results With the Decomposition of R^2 (in % of Total R^2).

	Multiple regression			Decomposition of R^2		
	β	*t*	*p*	Shapley % R^2	LLCI	ULCI
Prospect	.26	2.71	.008	25.58	18.14	32.30
Concealment	.12	1.26	.211	19.10	13.04	27.20
Entrapment	−.57	−9.49	<.001	55.32	43.64	67.00
Observations				100		
Full model R^2				.75		

Note. LLCI and ULCI confidence intervals based on bootstrapping with 5,000 resamples. OLS = ordinary least squares; LLCI = lower level confidence interval; ULCI = upper level confidence interval.

representative sample of urban streets, these results provide solid support for the applicability of prospect–refuge based perspectives in explaining environmental safety perceptions in real-life settings. In a second study, we extended our investigations to the role of lighting in the safety appraisal process by including appraisals of the quality of the lighting in our regression model.

Study 2

The general aim of Study 2 is to examine the potential mechanisms through which, according to the prospect–refuge framework, appraisals of the quality of the lighting in an environment affect people's perception of the safety of that environment. Following previous findings from the literature, we expect appraisals of the quality of the lighting to be positively associated with perceptions of environmental safety. More importantly, based on the findings presented by Haans and de Kort (2012), we expect that this relation between perceived quality of the lighting and perceived environmental safety is mediated, at least partially, by co-occurring variation in appraisals of prospect, concealment, and entrapment.

Method

Participants and design. We employed a within-subjects design in which participants evaluated the perceived quality of the lighting of the environments in our stimulus set. The sample comprised 46 participants (22 males and 24 females, M_{age} = 30.37, SD_{age} = 14.51, age range = 18-62 years). None of the participants lived in either Best or Geldrop. The participants were registered in the JF Schouten participant database at Eindhoven University of Technology, Eindhoven, The Netherlands, and responded to an invitation to participate in our study. Participants required approximately 1 hr to complete our study and received €10 as compensation for their participation.

Materials and measures. We used the same set of photographs as used in Study 1. Perceived quality of the lighting was measured using six 5-point response format items (e.g., "How good or poor do you think the quality of the lighting in this nocturnal environment is?") ranging, for example, from 1 (*very poor*) through 3 (*neither poor nor good*) to 5 (*very good*). For a complete overview of the items used, see Online Appendix A.

Initially, we created two separate measures: one measuring perceived quality of the lighting (Items 1-3) and one measuring perceived darkness of the environment (Items 4-6). Both measures were highly correlated ($r = .96$, $p < .001$). In fact, a principal-axis factor analysis with oblique rotation revealed that we could not distinguish these two measures as measuring distinct concepts. Therefore, we collapsed all six items into one measure and used this measure in the reported analyses. We calculated the average of the six items for each stimulus and used this aggregate score in our analyses ($\alpha = .87$).

Procedure. The procedure and conditions of Study 2 were analogous to those of Study 1, except that after viewing each stimulus, all participants now responded to the six items of the perceived quality of the lighting measure.

Results and Discussion

We added the aggregated perceived quality of the lighting score as a new variable to the dataset containing the prospect, concealment, entrapment, and perceived environmental safety measures obtained in Study 1 (see Table 1 for descriptives). All of the reported analyses are on the level of the stimulus. We first examined the correlations between the perceived quality of the lighting measure and the measures from Study 1 (see Table 2). We found that perceived quality of the lighting was positively correlated with perceived environmental safety ($r = .47$, $p < .001$) and prospect ($r = .76$, $p < .001$), and negatively correlated with concealment ($r = -.48$, $p < .001$) and entrapment ($r = -.49$, $p < .001$).

To test whether appraisals of the quality of the lighting predicted appraisals of environmental safety, we performed a simple regression analysis. The regression model accounted for approximately 20% of the variance in perceived environmental safety with $F(1, 98) = 27.28$, $p < .001$, $R^2 = .22$, and $R^2_{\text{adjusted}} = .21$. As expected, perceived quality of the lighting was significantly related to perceived environmental safety ($\beta = .48$, $t = 5.22$, $p < .001$). The regression model was robust across 100 split sample validations ($M_r = .48$, $SD_r = .079$, $M_R{}^2 = .22$).

Next, a multiple regression analysis was conducted with both the perceived quality of the lighting and the safety-related environmental characteristics as predictors. The combination of measures significantly predicted perceived environmental safety with $F(4, 95) = 72.31$, $p < .001$, $R^2 = .75$, and $R^2_{\text{adjusted}} = .74$. However, while the measures of the safety-related environmental characteristics predicted significantly over and above the perceived quality of the lighting measure with $R^2_{\text{change}} = .54$, $F(3, 95) = 68.53$, $p < .001$, the perceived quality of the lighting measure did not predict significantly over and above the measures of the safety-related environmental characteristics with $R^2_{\text{change}} = .01$, $F(3, 95) = 1.99$, $p = .161$. Based on these results, perceived quality of the lighting appears to offer little additional predictive power beyond that contributed by appraisals of prospect, concealment, and entrapment.

Taken together, these findings suggest that the positive correlation between perceived quality of the lighting and perceived environmental safety may be accounted for by co-occurring variation in appraisals of prospect, concealment, and entrapment. To test for such mediation, we used the bootstrapping method for multiple mediation by Preacher and Hayes (2008, 2004). See Figure 2 for a representation of the mediation model we tested, and Table 4 for a summary of the results of our mediation analysis.

The results of the mediation analysis show that perceived quality of the lighting is positively related to prospect, and negatively related to concealment and entrapment (see *a*s in Table 4). Our results also confirm the multiple regression analyses, showing that perceived quality of the lighting (total effect), and prospect and entrapment (see *b*s in Table 4) were significantly related to perceived environmental safety. The bootstrapping method provides estimates and bias corrected confidence intervals for the indirect effects in the model. If the confidence intervals do not contain zero, the estimate of the indirect effect is significant. Following this criterion, the results show that the indirect effects through prospect and entrapment were significant, but that the indirect effect through concealment was not. Moreover, the direct effect of perceived lighting quality on safety perception was not found to be statistically significant (see the direct effect c′ in Table 4). Importantly, our results suggest that the positive relation between perceived lighting quality and safety perception is completely accounted for by the relation between lighting quality and appraisals of prospect and entrapment.

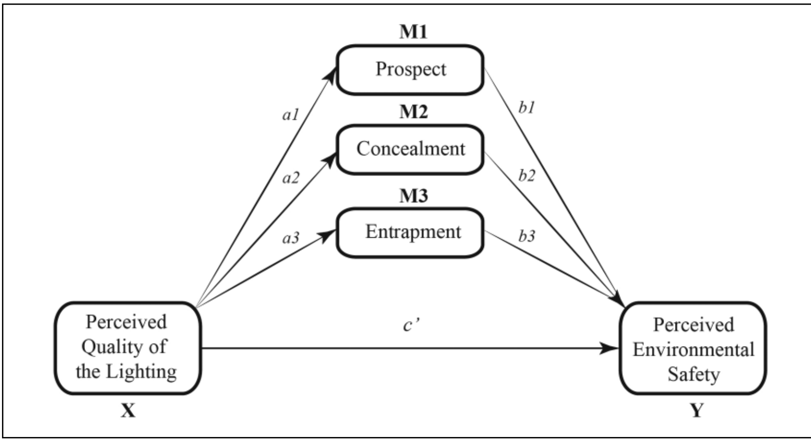

Figure 2. The mediation model linking appraisals of lighting with perceived environmental safety and the safety-related environmental characteristics.

Table 4. Summary of Mediation Analysis Results.

Independent variable	Total effect ©	Direct effect (c')	Mediator	First stage (a)	Second stage (b)	Indirect effect (ab)	95% CI of indirect effect	
							LLCI	ULCI
Quality of lighting	.476***	−.127	Prospect	.787***	.410***	.322	.103	.593
			Concealment	−.381***	.241	−.092	−.240	.020
			Entrapment	−.447***	−.833***	.372	.214	.574

Note. Regression weights are reported in unstandardized units. All measurement scales ranged from 1 to 5. Reported confidence intervals are bias corrected; 95% confidence intervals based on bootstrapping with 5,000 resamples. LLCI = lower level confidence interval; ULCI = upper level confidence interval.
***$p < .001$.

General Discussion

In two studies, we took a prospect–refuge perspective (e.g., Fisher & Nasar, 1992; Nasar et al., 1993) to investigate how lighting and other physical attributes (i.e., prospect, concealment, and entrapment) affect people's judgments of the safety of urban streets during nighttime. By employing a large and representative—and thus more ecologically valid—sample of urban streets as stimulus materials, we aimed to complement existing research that has predominantly employed factorial designs.

Safety-Related Environmental Characteristics and Perceived Environmental Safety

Our findings confirm previous findings highlighting the importance of appraisals of prospect, concealment, and entrapment in the safety appraisal process (e.g., Blöbaum & Hunecke, 2005; Fisher & Nasar, 1992). The results from Study 1 demonstrate that the predictive power of appraisals of prospect, concealment, and entrapment robustly accounted for approximately 75% of the variation in people's evaluations of the safety of urban environments.

In line with results presented by Blöbaum and Hunecke (2005), our results show that appraisals of the extent to which the environment offers opportunities to escape in case of an emergency (i.e., entrapment) have the largest effect on the perception of environmental safety during nighttime. Higher levels of entrapment were associated with significant decreases in perceived environmental safety. Appraisals of the extent to which the environment offers a good overview to an observer (i.e., prospect) were found to significantly predict perceived environmental safety. Environments offering higher levels of prospect were associated with higher judgments of perceived environmental safety. After correcting our regression analysis for the high multicollinearity between appraisals of prospect, concealment, and entrapment, we also found that the extent to which the environment offers hiding spots for potential offenders (i.e., concealment) accounted for a significant percentage of variance in the full regression model (see Table 3). Given our large and representative sample of urban streets, these results provide solid support for the applicability of prospect–refuge based perspectives in explaining environmental safety perceptions in real-life urban settings.

Lighting and the Safety-Related Environmental Characteristics

In Study 2, participants evaluated the quality of the lighting in each of the 100 photographs used in Study 1. Considering these appraisals of lighting in isolation, our results indicated that perceived quality of the lighting explained a small to moderate 20% of the variance in perceived environmental safety. In accordance with a large body of evidence (e.g., Blöbaum & Hunecke, 2005; Boomsma & Steg, 2014; Fotios et al., 2015; Loewen et al., 1993; Lorenc et al., 2013; Welsh & Farrington, 2008), lighting quality was positively related to perceived environmental safety.

In line with previous research (van Rijswijk et al., 2016), we found moderate to strong correlations between appraisals of lighting quality, prospect, concealment, and entrapment. This suggests that these physical attributes are correlated in our ecological environment. Such strong correlations between predictors complicate making inferences about the relative importance of these environmental characteristics. Furthermore, establishing such correlations reveals that the assumption of factorial independence underlying some of the existing empirical work employing factorial designs (e.g., Blöbaum & Hunecke, 2005; Loewen et al., 1993) is untenable. As a result, the interpretation of main and interaction effects reported in these studies should be done with care.

While additional research is needed to uncover the nature of these correlations, several authors have suggested that better lighting may increase people's sense of safety by increasing prospect, and reducing concealment and entrapment (e.g., Boyce & Gutkowski, 1995; Haans & de Kort, 2012). The results from our mediation analysis support such a hypothesis. We found that the correlation between lighting quality and perceived safety was accounted for by co-occurring variation in appraisals of prospect and entrapment. These findings provide evidence for the idea that lighting influences safety perceptions indirectly through its effect on those environmental characteristics that are important for the safety appraisal process. Interestingly, our results do not provide evidence for a potential direct effect of lighting above and beyond its effect through prospect and entrapment.

Beyond providing visibility for basic tasks such as object detection, lighting may thus be targeted to increase site-specific perceptions of environmental safety by optimizing the salience of safety-relevant environmental characteristics. For example, lighting may be employed to highlight those environmental characteristics that facilitate escape from a dangerous situation (e.g., an escape route or access to help). Our findings suggest that optimizing the uniformity of the lighting distribution, thus minimizing the contrasts and shadows that are expected to influence appraisals of prospect and concealment, may positively affect perceptions of environmental safety. Future research may further validate and extend the current findings by focusing more specifically on examining the suggested link between lighting characteristics and safety-related informational cues in the environment.

While the study by Haans and de Kort (2012) was performed in one specific location on a university campus, our results corroborate their findings. Yet, our results also deviate from their findings in two respects. First, we did not find appraisals of concealment to be a significant mediator of the effect of lighting appraisals on perceived safety. This is most likely a consequence of the lack of a direct effect of concealment on perceived environmental safety as observed in Study 1.

Second, while Haans and de Kort (2012) reported a small direct effect of lighting on perceived safety after accounting for the influence of the mediating variables (i.e., partial mediation), our results suggest that appraisals of lighting do not affect perceived environmental safety beyond the effect of the safety-related environmental characteristics (i.e., full mediation). One possible explanation for this discrepancy is the number of different streets considered in the two studies: one in the case of Haans and de Kort, and a large sample of 100 environments in Study 2. Another possible explanation is that where Study 2 deals with appraisals of the quality of the lighting in environments depicted by photographs, Haans and de Kort's findings resulted from a field experiment in which participants had direct exposure to the street and the lighting. The method of using photographs as stimulus material for obtaining assessments of a wide range of environmental characteristics has been validated by previous research (e.g., Stamps, 1990, 1993, 2010). However, these studies did not consider assessments of lighting. More research is needed to test the robustness of the current findings in situations of more direct exposure to the environment and the lighting therein.

Limitations

Some limitations may be identified with respect to the presented studies. First, our results with regard to the role of lighting should be considered with some caution, as the correlational design of the current studies is less suitable for making inferences about the causal chains underlying mediation processes (e.g., Spencer, Zanna, & Fong, 2005). Although the specific mediation path we test is guided by a theoretical model of how lighting may affect safety perceptions, the specification of independent and mediator variables does not logically follow from the data. In a statistical sense, it would be equally valid to test a completely different mediation model, for example, one where the effect of entrapment on perceived environmental safety is mediated by changes in lighting quality. Therefore, additional experimental studies are needed to make more solid claims about the mediating role of environmental characteristics in explaining the effects of lighting on safety perceptions. Experiments are needed that can demonstrate that manipulation of lighting indeed leads to changes in appraisals of prospect, concealment, and entrapment (i.e., the *a*-path in our mediation model, see Figure 2). Preliminary evidence for such causal effects is, however, provided by Haans and de Kort (2012). Moreover, more experiments are needed to demonstrate that manipulation of prospect, concealment, and entrapment will in fact lead to changes in perceived environmental safety (i.e., the *b*-path in our mediation model, see Figure 2). However, the independent manipulation of all three environmental characteristics may not turn out to be easy given the correlations between prospect, concealment, and entrapment observed in Study 1.

Second, to minimize possible spurious correlations between environmental characteristics and perceived environmental safety, independent groups of participants evaluated the photographs either on perceived environmental safety or on the three environmental characteristics. However, the latter evaluations were all done by the same group of participants. As a result, the strong correlations between prospect, concealment, and entrapment observed in Study 1 may be artificially inflated (e.g., due to common method bias; for example, Campbell & Fiske, 1959). However, a recent study in which these three characteristics were independently evaluated by different groups of participants yielded similarly strong correlations (van Rijswijk et al., 2016).

Third, we have stressed the importance of using stimulus materials that comprise a large and representative sample of the ecological environment. Although we believe that the large variety in the selection of environments used in our two studies represent a significant improvement over the limited set of locations commonly used in existing research, the selection still reflects the researchers' on-site decision about which environments to include in the set. As such, the selection cannot be said to be truly random, and future research may address this issue by using more thorough random sampling methods.

Fourth, by aggregating over participants' individual responses, and thus by analyzing our data on the level of the stimulus, the present studies have primarily focused on examining the validity of environmental cues in determining the safety of an environment. As such, we have disregarded any potential differences that may exist in how individuals use these environmental cues in the safety appraisal process. For example, it may well be that some individuals are more susceptible to safety-related environmental information, such that appraisals of prospect, concealment, and entrapment are more heavily weighted when forming a judgment about the safety of an environment (see, for example, Blöbaum & Hunecke, 2005; van Rijswijk et al., 2016).

Fifth, the controlled lab setting in which our studies were performed, while certainly advantageous for testing a large sample of environments, introduces potential drawbacks for investigating the effect of lighting on perceived environmental safety. For example, although the participants were instructed to imagine walking alone in the depicted environments, their presence in our safe laboratory will probably not have put them in the same emotional state as when actually walking alone in public space at night. Future research may be aimed at replicating our findings by having participants evaluating a representative sample of urban streets in situ.

Sixth, the assessment of the quality of the lighting was primarily focused on the spatial brightness aspect of lighting. Other aspects of lighting such as light distribution, uniformity, or glare were not assessed. Given that these, and other, aspects of lighting may also affect safety perceptions, future research may extend the current findings by investigating how different aspects of lighting affect perceptions of safety-related environmental characteristics (see, for example, Nasar & Bokharaei, 2017a, 2017b).

Finally, although we obtained a large and representative sample of urban streets from the ecological environment as stimulus materials, we did not obtain a large and representative sample of participants. The decision to include a relatively small sample of participants was mainly due to the large number of urban scenes that had to be evaluated. For similar reasons, we decided to use photographs rather than in situ evaluations, and refrained from obtaining physical measurements of the urban streets included in our stimulus set. However, we acknowledge that the inclusion of objective measurements, such as horizontal illuminance and street width, in prospect–refuge based models would greatly enhance our understanding of how people use physical characteristics of the urban environment in the formation of safety judgments (see, for example, Nasar et al., 1993).

Conclusion

Despite these limitations, our correlational studies support findings from existing research with respect to the role of prospect, concealment, and entrapment in explaining people's perceptions of the safety of urban environments during nighttime. As we used a large and representative—and thus more ecologically valid—sample of urban streets, our research provides more convincing evidence for the generalizability of prospect–refuge based models to real-life urban situations. In addition, we confirm and extend existing research by demonstrating that appraisals of lighting, prospect, concealment, and entrapment are highly correlated in our ecological environment. Although more research is needed to uncover the nature of these correlations, our results suggest that the positive effect of lighting on people's safety judgments can be explained by light affecting the perceived prospect and entrapment of urban streets.

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