Shedding light on safety perceptions : environmental information processing and the role of lighting

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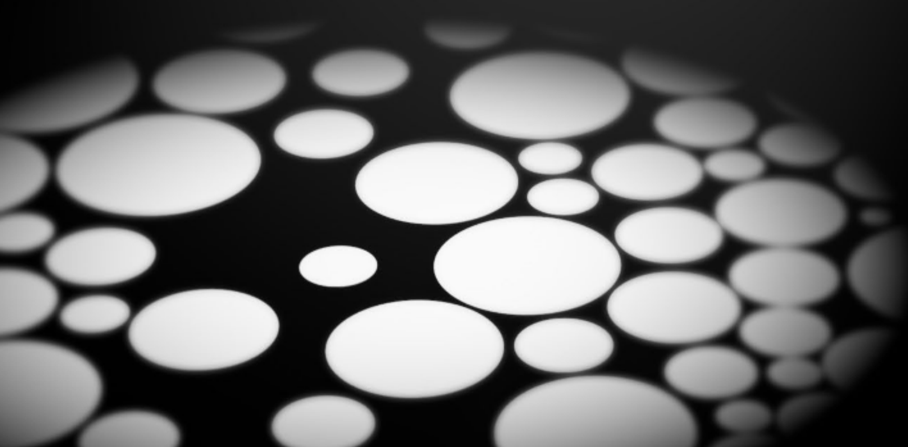
Leon van Rijswijk



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environmental information processing and the role of lighting

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven,
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Het onderzoek dat in dit proefschrift wordt beschreven is uitgevoerd in overeenstemming met de TU/e Gedragscode Wetenschapsbeoefening.

Content

Chapter 1

Introduction

Recall the last time you were walking alone after dark, strolling along a neatly lit pavement. You may have been walking home from a friends' house, or you may have been on your way to the supermarket for some last minute grocery shopping. Did you feel generally at ease during your walk? Or did you feel uneasy, perhaps even though there were no immediate causes for alarm, even though there was not even anyone else around? Have you ever wondered how the physical characteristics of our surroundings influence the way in which we perceive the world around us? In the current thesis, we will examine in depth how we use information available in our immediate surroundings to form judgments about the safety of the environment. In this endeavor, we will extend special consideration to understanding the role of lighting – a feature of the environment that is often intuitively associated with the experience of safety in public space.

Lighting for safety

One of the most basic needs for humans may be the need to feel safe. This is not merely evident from our personal experiences in daily life, but also from the attention that safety receives in public discourse. Even today, in an era that is historically among the safest to be alive, one has but to turn on the television set, read a newspaper, or attend to any kind of online news source to appreciate that much of current societal debate revolves around issues of safety.

In dealing with increased public consideration of public safety, much attention of municipalities and other governmental bodies will typically be directed at implementing measures that control the objective risks that individuals are exposed to (e.g., incidence of crime). However, although crime rates and other tangible manifestations of low levels of safety may indeed substantially affect daily life (e.g., Hale, 1996; Skogan, 1986; Brunton-Smith & Sturgis, 2011), the factors that influence a person's immediate sense of safety extend beyond mere objective indices of safety (e.g., Warr & Stafford, 1983; Hale, 1996). In other words, being safe is not the same as feeling safe. For instance, the incidence of crime associated with particular urban areas and the actual psychological experience of vulnerability to crime in these areas frequently mismatch (e.g., Fattah, 1991; Brantingham, Brantingham & Butcher, 1986; Brantingham & Brantingham, 1995), reflecting the complex relationship between the probability of being victimized and a person's immediate sense of safety. Previous research has associated feelings of insecurity with a number of negative consequences, such as an increase in people who avoid leaving their home after dark (Warr 1985; 1990), social isolation as a result of severely limiting daily activities (Keane, 1998; Lorenc et al., 2013), and detrimental effects on physical and mental well-being (e.g., Stafford,

Chandola, & Marmot, 2007; Jackson & Stafford, 2009; Moons & Shields, 2015). In effect, perceived safety is important in and of itself, as feelings of insecurity, even when seemingly unjustified, affect people in ways similar to actually being at risk.

The complex nature of crime and the sense of personal safety is reflected by the wide range of measures that are often employed with regard to crime prevention and/or enhancing feelings of safety (e.g., WAPC, 2006; Crowe, 2000). Still, amidst the myriad of potential measures, implementing or improving public lighting remains one of the most familiar strategies for designing-out crime and enhancing feelings of safety; certainly the one explored most thoroughly (Cozens, Saville & Hillier, 2005). Hence, most urban residential areas are now characterized by neatly organized poles. In any of its past and present forms, public lighting has facilitated the subduing of the nightly shroud of darkness and all the inconveniences and terrors that this darkness (supposedly) brings forth. In a relatively short amount of time, public lighting has managed to pervade the daily life of virtually every inhabitant of the world's urbanized regions, up to the point where it may no longer be an explicit part of conscious experience – noticed only when it is not present or not working properly.

The evidence for public lighting interventions

One of the central ideas underlying the proliferation of public lighting is that better or more lighting is both negatively related to the incidence of crime and positively related to subjective experiences of safety. A recent review by Welsh and Farrington (2008) examined studies investigating the effect of public lighting interventions on the incidence of crime, concluding that public lighting interventions may indeed significantly decrease the overall incidence of crime. Of the thirteen studies under consideration in the review, ten studies reported significant decreases in the incidence of crime, while the other three demonstrated neither a significant decrease nor a significant increase in the incidence of crime.

In contrast to the conclusion by the Welsh and Farrington review, past influential reviews have often concluded that the effect of public lighting interventions on crime reduction is non-existent (e.g., Ramsay & Newton, 1991; Tien, O'Donnell, Barnett, & Mirchandani, 1979). However, these past reviews may be criticized on the basis of a number of methodological flaws which significantly reduce the credibility of their conclusions (see also Pease, 1999). For example, the UK Home Office commissioned review by Ramsey and Newton did not specify a transparent set of rules on the basis of which studies were considered for review, and appears unnecessarily biased against including any studies showing positive results of public lighting interventions. In addition, the conclusion of the review was effectively based on a single evaluation study by the UK Home Office department (i.e., Atkin, Husain, & Storey, 1991), which primarily relied on differences between the day-time and night-time incidence of crime as the main dependent measure of change in crime rates. One problem with relying on the day-time incidence of crime as a baseline is that it fails to take into account potential effects of lighting improvements during the day. Thus, while improvements in public lighting may be found to decrease both the incidence of crime during the night as well as during the day (e.g., through increased informal surveillance resulting from increased community bonding, see Welsh & Farrington, 2008), the use of differences between day-time and night-time crime rates as measure of crime reduction may lead researchers to erroneously conclude there is no effect of lighting improvements on crime reduction. In fact, this is precisely what seems to have happened in the Home Office evaluation study (see Pease, 1999).

Another prominent review was commissioned by the US Home Office department in 1979 (Tien et al., 1979). Compared to the UK review, the US review was more systematic and forthright in their description of the rules for inclusion and exclusion of studies considered in the review. Yet, Tien and colleagues only considered studies in which a public lighting intervention was the single manipulation in the evaluation design. Such a strict selection criterium not only significantly reduces the amount of studies available for consideration given that large-scale interventions typically include a number of manipulations, but biases the sample against any studies showing contingent effects of lighting on crime reduction (e.g., improving the lighting may be more effective in conjunction with other manipulations of the environment aimed at improving visibility).

Although the number of studies included in the Welsh and Farrington (2008) review was relatively small, the selection criteria were clearly formulated and importantly include the requirement of before-and-after measures and at least one experimental and one comparable control area. In addition, the authors also consider studies that include other manipulations besides lighting, as long as lighting improvements were the main manipulation. These considerations at least appear to lend some credibility to the notion that public lighting interventions may indeed decrease the incidence of crime (but see Marchant, 2010; 2004).

While the empirical evidence is still mixed, the idea that street lighting reduces crime rates seems to fit the intuition of many people that lighting the streets at night will prevent malevolent individuals from engaging in misconduct, for example by making visible criminal behavior and by promoting social control among residents. Yet, there are some findings that do not quite fit such a simple explanation. For example, some of the studies described in Welsh and Farrington's review report that public lighting interventions lead to a decrease in the incidence of crime during day-time as well as during night-time. The lack of explanations offered for these kinds of findings points out a hiatus in our understanding of how public

lighting affects crime. There may yet be many more factors that play a role in explaining the effects of public lighting implementations and improvements on the incidence of crime (e.g., community bonding and social capital, see Pease, 1999; Welsh & Farrington, 2008).

In contrast to conclusions about the effect of public lighting improvements on the incidence of crime, the reviews generally agree about the positive effect of public lighting on perceptions of safety (e.g., Welsh & Farrington, 2008; Fotios, Unwin & Farrall, 2014; Lorenc et al., 2013; Tien et al., 1979; Ramsey & Newton, 1991). Interestingly, Tien et al. (1979), who concluded from their review that there is no significant relationship between public lighting and the incidence of crime, did acknowledge that "[…] street lighting can be assumed to affect the fear of crime" (p. 93). Similarly, despite their conclusion that public lighting has very little effect on crime itself, Ramsey and Newton (1991) recognized that improving public lighting appeared to aid reduction of the public's fear of crime. Some further support may be found in a series of studies by Painter and Farrington (e.g., Painter, 1994; 1996; Painter & Farrington, 1997; 1999), who assessed the subjective impact of public lighting interventions using both attitudinal measures (e.g., fear of specific criminal behaviors such as an attack or rape) as well as behavioral measures (e.g., counting the number of pedestrians using the street). These studies demonstrated that properly installed or tailored lighting improvement programs were associated with decreases in reported fear of crime, and an increase in pedestrian street use at night (but see Boyce & Gutkowski, 1995).

Taken together then, while the evidence for the idea that lighting interventions may be successfully implemented to decrease the incidence of crime is still mixed, we find more convincing support for a positive effect of (well-targeted) lighting interventions on subjective experiences of safety. Yet, similar to our lack of understanding of how public lighting may affect the incidence of crime, the process through which public lighting affects perceptions of safety is poorly understood; a hiatus in our understanding that is becoming increasingly apparent in the light of recent developments in public lighting.

New developments in public lighting

The way we light our streets at night has not changed very much since the end of 19th century, when Edison's improvements to the incandescent light bulb popularized the light source that was both durable and controllable (e.g., Painter 1999; 2000). However, public lighting is currently facing radical changes due to technological innovations and a growing societal awareness of problems related to climate change and impending shortage of fossil fuel reserves. One ecological concern with respect to public lighting is an excess of light during the night, leading to luminous pollution that may severely affect ecological systems (see e.g., Longcore & Rich, 2004; Navara & Nelson, 2007). Another concern is not so much the abundance of light at night, but the waste of valuable energy resources it brings about; especially considering that our streets are lit even when there are no street users present. The growing awareness of these type of concerns is accompanied by an increased societal demand on rethinking the way in which we light our streets at night.

Aside from societal demands, new innovations in lighting technology also provide an impulse to think about new public lighting solutions. Important in this respect are the current developments in solid state lighting, for example Light Emitting Diodes (LEDs) or Organic Light Emitting Diodes (OLEDs). These lighting sources are potentially more energy-efficient than traditional lighting solutions, and their small size allows for novel sorts of public lighting; a sort that may be less dependent on neatly distributed poles – or that does not require poles at all. With the flexibility of OLEDs, for example, any kind of street furniture could potentially become a luminaire. Solid state lighting also allows for more control over illumination output and spectral distribution, and the integration of sensing technologies into these lighting innovations will allow for intelligent dynamic outdoor lighting systems. Such systems will be capable of detecting the presence of different types of street users and adapting output illumination levels accordingly; providing light only when and where it is needed most, while selectively dimming the rest of the environment (e.g., Haans & de Kort, 2012). These innovations thus offer promising solutions for implementing sustainable outdoor lighting systems.

Solid state lighting will offer municipalities and light designers a vast amount of options in deciding how to illuminate public space. The challenge is to benefit most from the potentials of solid state lighting (e.g., in terms of aesthetics, dynamics, and energy savings) while at the same time ensuring optimal human functioning during the evening and at night. For example, the dimming of light during certain periods of the night inevitably requires a trade-off between energy savings on the one hand and the experience of safety on the other hand. While intelligent dynamic lighting systems may optimize this trade-off, new questions will become relevant that were less pertinent for more conventional public lighting systems (e.g., Haans & de Kort, 2012). What parts of the environment should we lit when a specific street user (e.g., pedestrian, cyclist) is detected? Where and to which level might we dim the lighting without affecting basic human functioning and experiences of safety? To implement novel solid state lighting solutions in the proper way, and thus to benefit most from the possibilities they offer, existing lighting recommendations and regulations, based on more restricted conventional lighting systems, may not be sufficient any longer. Yet, what is needed most is not more and newer lighting recommendations as such, but rather a more theory-based, and thus justifiable, approach to developing lighting recommendations. A more profound understanding of how lighting affects our experience

of safety will allow lighting designers and policy makers to design public lighting systems and develop lighting recommendations that optimize the intricate balance between societal and ecological demands, technological possibilities, and human functioning at night.

Lighting and the sense of safety

An interesting reflection on the bulk of the studies investigating the impact of public lighting on more subjective measures of safety is that, while their findings converge toward a positive effect of public lighting interventions on perceptions of safety, they generally do not provide us with a deeper understanding of the path through which lighting may influence these safety perceptions.

Based on a literature review, Boyce and Gutkowski (1995) suggest that the major factor mediating the effect of lighting on safety perceptions 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). In contrast, Painter (1994) lists altered public perceptions due to physical improvement of the environment, increased social dynamics (related to changes in the sense of community, see Pease, 1999), and a "general feel good factor" (p. 118) among the possible ways in which public lighting could increase safety perceptions. These latter considerations highlight an interesting issue; the effect of these lighting improvement programs on safety perceptions may not necessarily be a direct result of improving the lighting itself, but rather be the result of some indirect effect such as community bonding or social vigilance. If this is the case, these positive effects may also be achieved by other means than improving street lighting.

However plausible these suggestions (and other suggestions we have omitted) may be, there is, to our knowledge, little to no empirical work that directly investigates any of the suggested paths through which public lighting may affect people's safety perceptions. In contrast, more general determinants of the sense of safety are much more extensively covered by the literature (e.g., Skogan, 1986; Hale, 1996; Appleton, 1975; Kaplan & Kaplan, 1989; Fisher & Nasar, 1992; Fotios, Uttley, Cheal, & Hara, 2014). It may thus be informative to continue our discussion from a broader perspective, examining what we broadly know about the determinants of our sense of safety.

What affects our immediate sense of safety?

Research on the determinants of the immediate sense of safety is highly fragmented with each domain studying aspects of the phenomenon in relative isolation. Within the large set of determinants of perceived safety identified by previous research, a useful distinction can be made between more distal factors and more proximate episodic factors, which may influence the sense of safety on different levels in any given situation. Distal factors refer to those individual and socio-cultural factors that are relatively independent of the specific environments people find themselves in (e.g., biological and personality characteristics, preconceptions, and prior experiences). However, these distal factors may affect the sense of safety by shaping the processing and interpretation of safety-related environmental information. In turn, any experiences during a specific episode may alter these distal determinants by shaping a person's personality, knowledge, and preconceptions. In contrast, proximate episodic factors refer to those factors that are intrinsically linked to a specific situation, and may affect the sense of safety by providing the basic informational cues for assessing the safety of a current situation. In other words, proximate factors refer to the available environmental information that people may use to form a judgment about the safety of their surroundings.

Surveying the relevant literature on the determinants of the sense of safety, one may discern a considerable amount of different outcome variables employed to measure the sense of safety. Some prominent examples include studies investigating such responses as the fear of crime (e.g., Fisher & Nasar, 1992; Loewen, Steel, & Suedfeld, 1993; Liska & Baccaglini, 1990), perceptions of danger (e.g., Blöbaum & Hunecke, 2005), or perceived personal safety (e.g., Haans & de Kort, 2012). Yet, the apparent dissimilarities between these concepts may primarily reflect specific terminology. For instance, while the use of a concept such as fear of crime may suggest otherwise, the majority of these studies examined determinants that do not constitute an immediate and identifiable source of threat - a basic requirement for the manifestation of a fear response (e.g., Sylvers, Lilienfeld & LaPrairie, 2011; Grillon, 2008; Tellegen, 1982). In fact, given that in most of the studies impending threats cannot be linked to an identifiable source in the immediate environment, measures of fear of crime and perceptions of safety or danger may be more closely related to perceptions of mostly unseen, *potential* threats, and consequently affect an observers' temporary state of anxiety rather than giving rise to a fear response.

Importantly, while both may share some experiential characteristics (e.g., negative valence), there are marked psychological, behavioral, and physiological differences between fear and anxiety. For example, where fear is associated with phasic (i.e., brief) changes in the organism, such as the activation of immediate defense mechanisms and active coping behaviors, anxiety is a temporary but sustained state involving risk assessment, increased overall sensitivity, and the engagement in avoidance behavior and other precautious actions (e.g, Sylvers et al., 2011; Davis, 1998; Tellegen, 1982). Given that these differences are thus expected to influence both the research approach as well as the correct interpretation

of outcomes, researchers investigating determinants of perceived safety should be explicit about which type of responses are (intended to be) measured. In the current thesis we define perceived personal safety as a sustained but temporary state during which there is an absence of the anxiety to become a victim (e.g., Haans & de Kort, 2012). We will now briefly discuss three main domains of research that have examined determinants of perceptions of personal safety: (a) individual and socio-cultural determinants, (b) the critical task paradigm, and (c) socio-physical determinants in the immediate environment.

Individual and socio-cultural determinants

Individual and socio-cultural determinants are relatively independent of a specific situation, but nonetheless influence the sense of safety in that setting (i.e., distal influences). These determinants may range from individual characteristics, preconceptions, and past experiences, to cultural norms and social representations of crime. For instance, ample research has demonstrated that men feel more safe than women (e.g., Fisher & May, 2009; Boomsma & Steg, 2014; Blöbaum & Hunecke, 2005; Fisher & Nasar, 1992), an effect that may in turn be influenced by differences in the (perceived) vulnerability to crime, predominant cultural ideas, norms and social representations of crime, and notions about how crime affects both sexes (e.g., Skogan & Maxfield, 1981; Brownlow, 2005; Koskela, 1997; Sur, 2014). In addition, previous personal experiences as a victim or witness of crime (Skogan & Maxfield, 1981), information about crime from social networks (Skogan, 1986), or media coverage of crime (Liska & Baccaglini, 1990; Heath & Gilbert, 1996) can influence people's perceptions of safety by shaping the representation of social spaces (see Valera & Guardia, 2014).

Critical tasks

In the second domain, research is primarily aimed at identifying a pedestrian's critical perceptual tasks. The underlying idea is that in order to function properly in our environment, we should be able to execute certain critical perceptual tasks (e.g., object detection), and that the impediment of the execution of these critical tasks may result in feelings of insecurity. Although more distal factors may also influence critical task execution, this approach is mainly concerned with more proximate determinants of the sense of safety, particularly with the role of lighting in the facilitation of these critical tasks. Indeed, the critical task paradigm is currently the principal paradigm in urban lighting research, working on the assumption that pedestrians will start to feel insecure when dim light levels (or disability glare at high light levels) prevents them from executing the perceptual tasks important for their sense of safety. One of the most extensively examined critical tasks in urban lighting research is face recognition, which was proposed by Caminada and van Bommel (1980) as the main critical perceptual task for attaining a sufficient sense of safety. However, while face recognition is certainly one of the most prominent critical tasks, receiving a fair share of attention in the design of lighting implementations and development of lighting recommendations, the idea that face recognition is the most critical task for the sense of safety has not yet been validated empirically. Some authors, for example, have argued that being able to make a timely judgement about the intention of other people could well be more important for the perception of safety than identifying faces (Fotios & Raynham, 2011).

A number of recent studies examined the critical perceptual tasks in a more empirical manner, employing mobile eye-tracking devices to identify gazing patterns and visual priorities in typical outdoor settings (e.g., Davoudian & Raynham, 2012; Fotios et al., 2014). For example, Davoudian and Raynham asked participants to walk three different residential routes and found that participants spent between 40% and 50% of the time looking at the pavement. Extending this paradigm, Fotios and colleagues employed a dual-task paradigm, in which participants performed a demanding auditory response task during their walks. The idea was that significant events that required attention would cause a drop in performance on the response task, thus distinguishing critical from non-critical gazing patterns. Their results replicated the findings from the former study, showing that a large amount of time is spent looking at the pavement. In addition, critical events were often associated with looking at other people in the participant's surroundings. Other objects in the environment, such as vehicles, or trip hazards were found to account for a fewer amount of the critical observations. These recent initiatives thus promise to provide a more thorough and evidence-based understanding of what the critical perceptual tasks are for the perception of safety.

Socio-physical determinants of safety in the immediate environment

The third domain of research focuses mainly on understanding how factors from a person's immediate environment affect their immediate sense of safety. While traveling through an environment, we are confronted with a massive amount of sensory information impinging on the senses, and an observer must select and weigh relevant informational cues in order to correctly infer certain relevant qualities from the setting that may not be directly perceived (e.g., Brunswik, 1952) – a process that may be characterized by an ongoing interaction between the individual and the socio-physical environment. These factors include, for example, the physical characteristics of the environment that, even in the absence of a visible threat, influence the sense of safety. Much of the empirical work on these safety-related physical characteristics is based on theories of environmental preferences, such as Appleton's (1975) prospect-refuge theory, or Kaplan and Kaplan's (1989) preference-matrix model, which identify relevant environmental characteristics that may play a role in the development of environmental preferences and (safety-related) environmental appraisals.

While acknowledging the important contributions of the other domains of research for understanding how the sense of safety develops, the current thesis focuses on examining how proximate safety-related physical characteristics of the environment (including lighting) affect perceptions of the safety of an environment. To this end, we adopt a functionalist information-processing perspective on environmental perception (e.g., Brunswik, 1952; Kaplan & Kaplan, 1989), highlighting the important role of processing relevant environmental information in the safety appraisal process. The following section provides a more elaborate discussion of the broader theoretical framework on which the work presented in the current thesis is based.

An environmental information-processing account of safety perceptions

According to Levy-Leboyer (1979/1982), early perception researchers, faced with the enormous complexity of environments and the problems this posed to the study of perception, sought ways in which they could simplify the environment. There was a strong belief among the majority of perception researchers, known as structuralists, that complex environments were nothing more than the sum of their constituent elements. Consequently, in the first half of the twentieth century most research on perception processes focused primarily on how specific, isolated objects are perceived (e.g., size, brightness, distance). Levy-Leboyer notes that the behavior observed in such laboratory studies is neglecting of the natural dynamic interrelations that occur between a person and his environment, that "[…] the environment is studied as something to which the individual is passively subject, […] because the individual is presented with unalterable conditions, […] which limit his freedom of action and his personal progress." (p. 14).

In response to the prevalent tradition of structuralism, Gestalt psychologists were among the first to claim that complex environments and stimuli possessed qualities that went beyond the simple objects that composed them (e.g., Koffka, 1935; Wertheimer, 1923). Early environmental psychologists integrated these ideas into a new research domain which focused on understanding behavior as it occurs in complex environments (Ittelson, 1973). While the existence of complex interrelationships between the individual and the environment certainly requires thoughtful consideration with respect to the representativeness of experimental designs (e.g., Brunswik, 1944; 1955), it does not imply that environmental perception can only be studied outside the laboratory. Rather, it requires that researchers interested in studying behavior in complex environments should avoid studying those situations that people rarely encounter on a daily basis (i.e., "that bearded lady at the fringes of reality"; Brunswik, 1955, p. 204) or those situations that are too abstract representations of reality (i.e., "a mere homunculus of the laboratory out in the blank"; Brunswik, 1955, p. 204). We will not develop a comprehensive understanding of complex environments without making use of stimuli that are a representative sample of ecologically possible environments (e.g., Brunswik, 1944).

Furthermore, the observer-environment relationship should not be regarded as a strictly unilateral relationship, but rather a dynamic one; we perceive the environment and the environment, in all its complexity, simultaneously influences the way we perceive it. Defined as such, it should be clear that the environment is a very broad and complex concept, one that has inspired much debate among environmental psychologists about the characteristics of environmental space (e.g., Lewin, 1936; Barker, 1968; Ittelson, 1973; Levy-Leboyer, 1979/1982). Such debates notwithstanding, the field of environmental psychology has provided us with a number of prominent theories that aid our understanding of how we achieve perceptual judgments about our surroundings (e.g., Brunswik, 1952; Gibson, 1979; Kaplan & Kaplan, 1989).

Functionalist theories of environmental perception

An important notion underlying the theories discussed in this section is that an organism's behavior is evolutionary shaped and adapted to the effective functioning of the organism in its environment (i.e., *functionalism*; see Brunswik, 1952; Gibson, 1979; Kaplan & Kaplan, 1989). To aid this effective functioning in the environment, an organism should be able to achieve accurate perceptual judgments about the environment through the processing of environmental information. For example, Kaplan and Kaplan (1989) have proposed an informational framework that asserts that information processing is key to effective functioning in the environment. This informational framework incorporates the notion of environments possessing certain qualities that we can employ to fulfil our basic needs (e.g., provide us with food, safety), including those qualities of environments that address our cognitive needs (e.g., facilitating the ease of processing sensory information). The Kaplans maintain that one of the most developed and important traits of the human species is their proficiency in thoroughly processing environmental information and that we are exceptionally well-equipped to extract the relevant information from the environment. For instance, the Kaplans describe how "even the briefest glimpse of the passing landscape provides information. This information does not depend on posted signs or neon lights. It is far subtler and generally not a part of one's awareness." (Kaplan & Kaplan, 1989, p. 50).

Thus, from a functionalist perspective, effective functioning in the environment depends to a great extent on the processing of environmental information. Yet, some of the objects of perceptual judgment, such as the perception of the safety of an environment, may not always be manifest to an observer. Brunswik (e.g., 1952; 1955) developed his model of probabilistic functionalism to deal with the issue how humans process environmental information to infer environmental qualities that may not be directly perceived.

Brunswik's lens model

Brunswik's notion of probabilistic functionalism emphasizes the active role an organism plays in the perception of its physical environment and provides a mechanism for how an organism's ecological niche, in turn, shapes these perceptual and cognitive processes. Brunswik argued that an organism's behavior is organized to reach an underlying goal, and that the achievement of accurate perceptual judgments based on the vast amount of sensory information that impinge on the organism's senses is instrumental to effective adaptation to the environment (hence *functionalism*). Moreover, the world in which an organism must function is complex and inherently uncertain. As a result, the available sensory information cannot be expected to have a deterministic meaning; the relation between informational cues in the environment and the observer's perceptual judgment is *probabilistic* at best (hence *probabilistic* functionalism).

Central to Brunswik's theory is the so-called lens model (see *Figure 1.1*), which explains how an organism, despite the probabilistic nature of its environment, realizes its goals by means of achieving accurate perceptual judgments. Through functioning in, and interacting with, their ecological environment, observers will learn to select and weight informational cues from the environment in the appropriate manner – appropriate in the sense that the selection and weighting process is optimally matched to the structure of the environment. At the base of the model lies the assumption that certain higher-order appraisals of the environment (*criterion* variables) are not directly available to an observer. Importantly, Brunswik discerns *distal stimuli* from *proximal stimuli*.[1] While distal stimuli may be thought of as more objective descriptions of the organism's physical environment (e.g., the presence of occluding edges or the density of the vegetation), proximal stimuli refer to the organism's more subjective interpretations of its physical environment. Given the often covert nature

1 Note that Brunswik utilizes terminology that is similar to the terminology we have used to describe different types of determinants of perceived safety. However, Brunswik's distal and proximal stimuli both refer to stimuli in the proximate environment, which are differentiated on the basis of the extent to which they constitute subjective interpretations by the perceiving organism. To avoid confusion, the terms distal and proximal stimuli will only be used in the current section on Brunswik's lens model. In the remainder of the thesis, distal and proximate will refer to the distinction between factors in one's immediate surroundings and factors that are relatively independent of the current situation.

of the criterion variable, observers must resort to informational cues provided by the distal stimuli and the proximal stimuli to infer the state of their physical environment, and Brunswik coined the term *ecological validities* to reflect the extent to which such informational cues are valid predictors of the actual state of the environment. For example, if the density of the vegetation in an environment is a strong negative predictor of the criterion variable, the ecological validity (which takes the form of a correlational relationship between the informational cue and the criterion variable) will be high.

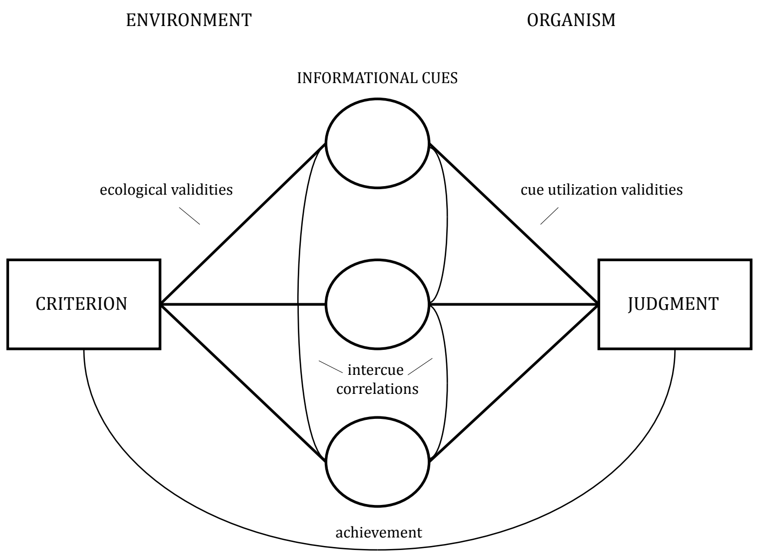

Figure 1.1. Brunswik's lens model.

Because of the enormous complexity that characterizes the physical environment, the relationship between the criterion variable and the informational cues will not be perfectly predictable, and an observer must infer the criterion by judging the importance and weight of the informational cues he observes. The more this *cue utilization* corresponds to the actual ecological validities of the different informational cues, the higher the achievement (i.e., the correlation between the observers' perception and the actual state of the environment) will be. To return to our example, assuming the density of the vegetation negatively influences the safety of an environment, correctly identifying this informational cue as important and applying it proper weights in one's judgment should result in a judgment about the safety of an environment that matches the criterion value of environmental safety.

Of course, our example is an oversimplified representation of this perception process; in reality an observer would be faced with a myriad of informational cues, all with their respective ecological and potential utilization validities. Due to the complex nature of the environment, the organism cannot be expected to rely on a very limited set of informational cues for inferring environmental qualities. Rather, informational cues are expected to be redundantly specified in the environment, such that the organism may infer a certain environmental quality from a large pool of potential informational cues in a wide range of settings (i.e., vicarious mediation; e.g., Brunswik, 1952). The selection of these informational cues and their utilization is decidedly idiosyncratic and highly dependent on, for example, past experiences or explicit knowledge of correlations between the criterion variable and the informational cues (e.g., an area that is infamous for robberies). According to Brunswik, feedback gained from repeated exposure to the discrepancy between one's perception and reality should lead to more accurate utilization of environmental cues and ultimately to a perception that more closely matches the actual state of the physical environment.

Gibson's affordances

In contrast to Brunswik's probabilistic functionalism, Gibson (e.g., 1979) advocated a theory of environmental perception that assumes that meaning in an environment can be directly perceived by an observer. This perspective entails the idea that the patterns of stimulation present in an environment impinge on our senses and directly convey meaning to an observer, without resorting to the use of more elaborate, interpretative cognitive processes. According to Gibson, an organism actively explores its environment, and through this exploration it detects certain invariant functional properties of objects in that environment (e.g., the hardness of a stone), which he termed affordances. These affordances may be viewed as disclosing relevant information about how one can interact with the different objects present within an environment.

At face value, Gibson's ecological perspective and Brunswik's lens model appear to differ to some extent in explaining the process of environmental perception. While Brunswik argues that we perceive the socio-physical environment by selectively attending to available sensory information, emphasizing the importance of higher order information processing, interpretation, and individual differences, Gibson maintains that we can directly perceive the socio-physical environment without resorting to complex interpretational processes, deriving meaning directly from the flow of information. Yet, both theorists agree on the basic premise that the purpose of the behavior of an organism is to effectively adapt to its environment (i.e., functionalism), and share the view that perception should not be studied in laboratories stripped of all references to the natural world, but rather in the context of the complex environments in which the perception process has developed (Brunswik, 1955; Gibson, 1979). Hence, both theories do not necessarily have to contradict each other. For example, Vicente (2003) has pointed out that we may regard Gibson's affordances as a special case within the lens model – the case where an environmental quality can be directly perceived by an observer and no subjective, probabilistic interpretation based on informational cues is necessary.

Safety-related characteristics of the environment

The functionalist approaches to environmental perception thus highlight the importance of processing relevant environmental information to effectively adapt to one's environment. However, acknowledging that information processing is paramount is not sufficient; if we aim to better understand the safety appraisal process, we should determine which relevant proximate environmental information may be used in this process. As mentioned before, most of the work investigating how environmental characteristics impact the perception of safety is based on two models of environmental preferences: Appleton's (1975) prospect-refuge theory and Kaplan and Kaplan's (1989) preference-matrix model. While these models are mainly concerned with determinants of environmental preference, a notion both models share is that environmental preferences reveal the environmental characteristics that aid effective functioning in the environment. The achievement of effective functioning may be indicated by experiences of safety, competence, and comfort (Kaplan & Kaplan, 1989), or by the satisfaction of basic needs (e.g., food, shelter, safety) – and thus the survival of the organism (Appleton, 1975).

Herzog and colleagues have investigated how Kaplan and Kaplan's (1989) notion of mystery, defined as the degree to which an environment holds the promise of future involvement and thus motivates further exploration, relates to perceptions of safety. In line with the preference-matrix model, Herzog and Miller (1988) found mystery to be a positive predictor of environmental preference. At the same time, however, they found mystery to be negatively related to the sense of safety. This apparent paradoxical relation between mystery, preference, and safety may suggest that mystery's specific role in the safety appraisal formation process depends on the specific combination with other environmental cues (e.g., Herzog & Kropschott, 2004; Herzog & Flynn-Smith, 2001), and/or that the role of mystery changes in situations where safety is at stake (Herzog, 1998).

More consistent results are typically found in studies that, based on the work by Appleton (1975; 1984), focus on proximate environmental influences on the perception of safety. Appleton asserted that in most species the satisfaction of basic needs is often dependent on a combination of the ability to see and the ability to hide (i.e., to keep information channels open without revealing information about oneself; see Appleton, 1984). His prospect-refuge theory predicts that environmental preference is based on the opportunities an environment offers to (a) have a clear overview over the situation (*prospect*), and (b) avoid being seen by potentially dangerous others (*refuge*). Although Appleton acknowledged that there are additional environmental qualities besides prospect and refuge that may be conducive to the survival of an organism, and likewise have an influence on environmental preferences, the prospect-refuge model has provided researchers with an important framework for investigating how appraisals of environmental characteristics impact people's perceptions of the safety of an environment. Most notably, Fisher, Nasar, and colleagues (e.g., Fisher & Nasar, 1992; Nasar, Fisher, & Grannis, 1993) have extended Appleton's prospect-refuge theory with some important insights, studying how subjective appraisals of environmental characteristics, referred to as *proximate cues* (Nasar et al., 1993), influence people's perception of that environment.

Fisher and Nasar (1992) recognized that refuge may have different meanings depending on whether you take on the perspective of a potential victim or the perspective of a potential offender. The prospect-refuge perspective predicts that people feel most safe in environments offering high prospect as well as high refuge. However, the presence of one or more hiding spots is exactly what a potential offender would prefer, rendering those refuges potentially dangerous to any passer-by, which may actually make people feel less safe in environments offering many hiding spots (i.e., refuge ambiguity; see Loewen et al., 1993). To avoid future misunderstandings, Nasar and Jones (1997) introduced the term *concealment* to indicate those environmental qualities that offer potential offenders a place to hide.

Second, Fisher and Nasar (1992) argued that there may be a third factor besides prospect and concealment that should be considered when we try to explain how perceptions of the safety of an environment are derived from perceptual judgments of safety-related environmental characteristics. They introduced the *ease of escape* as a factor in the model, which entails either the opportunity to flee the scene in case of a threat or the opportunity to come into contact with other people who are able to help you. Defining ease of escape in more similar terminology as prospect and concealment, *entrapment* refers to those physical environmental qualities that impose a barrier to escape the current setting (Nasar & Jones, 1997).

Thus, in short, the proximate cues framework asserts that people use appraisals of certain proximate environmental characteristics (i.e., prospect, concealment, and entrapment) to infer the safety of an environment. A number of studies have supported these assertions, showing that environments judged to offer high levels of concealment and entrapment, and low levels of prospect tend to be associated with higher levels of fear of crime (e.g., Fisher & Nasar, 1992; Nasar et al., 1993; Loewen et al., 1993; Nasar & Jones, 1997), higher perceived danger (e.g., Blöbaum & Hunecke, 2005), and more negative perceptions of safety (e.g., Haans & de Kort, 2012). For example, Blöbaum and Hunecke investigated the impact of environmental characteristics and personality characteristics on perceptions of environmental safety and found entrapment to be the single most important factor contributing to people's sense of safety.

Limitations of the proximate cues approach

However productive the proximate cues framework has proved to be in broadening our understanding of how people infer the safety of an environment from the available environmental information, some concerns may be raised with respect to the methodology typically employed in these studies – concerns that potentially undermine the credibility of the findings discussed in the preceding section.

One of the most important concerns is that the majority of previous studies employ an experimental approach in which each of the safety-related environmental characteristics is operationalized as an independent factor in a factorial design (e.g., Fisher & Nasar, 1992; Loewen et al., 1993; Blöbaum & Hunecke, 2005). For example, Blöbaum and Hunecke collected judgments of perceived danger for eight university campus areas that systematically varied in levels (i.e., high and low) of entrapment, concealment, and lighting. The authors proceeded to analyze the differences in appraisals of perceived danger between these areas using a mixed linear model and interpreted the results in terms of independent contributions of the different factors included in their design, concluding that entrapment was the most important environmental characteristic that influenced perceived danger. Underlying such an interpretation in these type of studies is the unverified assumption that all factors included in the design can be independently manipulated. Yet, a better overview will typically be associated with lower levels of entrapment and fewer opportunities for concealment, and safety-related characteristics of the environment may thus tend to covary substantially in the real world. In this respect, it is interesting to consider the figure presented by Fisher and Nasar (1992), showing how the areas selected for safety evaluations in their studies were distributed along levels of prospect and concealment (p. 44, Figure 3). From this figure, it is apparent that all areas exhibited either a combination of a high level of prospect and a low level of concealment, or a combination of low level of prospect and a high level of concealment. In combination with the absence of any areas exhibiting low levels of prospect *and* concealment, or areas exhibiting high levels of prospect *and* concealment, their sample of areas nicely illustrate the natural covariation of these variables. Artificially untying (Brunswik, 1956) variables that tend to covary naturally and cannot be separated easily in reality significantly reduces the representativeness of the experimental design, and likely poses a threat to the interpretation of any independent or interaction effects found in these studies. Examining the credibility of the findings reported thus far requires a complementary approach employing methodologies that do not rely on the assumption of factorial independence (e.g., correlational designs).

A related problem is that the sites included in these factorial designs are typically selected because they possess a certain configuration of the safety-related environmental characteristics (e.g., high prospect, low entrapment and concealment). A consequence of such selection may be that these environments represent 'extreme situations' in which the observed relationships between safety-related environmental characteristics and perceived environmental safety may be exaggerated. In addition, these sites are often sampled from very specific areas, most prominently on university campuses. As some authors have duly noted (e.g., Blöbaum & Hunecke, 2005), assessing environmental qualities on-site enhances the representativeness of the findings from these studies by accurately reflecting the actual experience people would have traveling through that particular environment. Yet, the explicit focus on university campuses (or a specific architectural site; see Fisher & Nasar, 1992) may run afoul of covering the wide range of environments that people typically encounter on a day-to-day basis. Consequently, we cannot yet be sure that the relationships between safety-related characteristics of the environment and perceptions of environmental safety found in these situations are generalizable to the wide range of environments we experience in our ecological niche, or merely idiosyncratic to the environments under consideration in these studies. What seems necessary is an extension of the range of environments we consider in our research, focusing on sampling those environments that more accurately reflect daily experiences in order to establish the ecological validity of the various findings in the field (see Brunswik, 1956).

Finally, while the proximate cues framework may provide us with a basic understanding of which (subjective) qualities of an environment may be important when it comes to people's judgments of safety, in our view it cannot explain sufficiently the mechanisms underlying environmental assessments. Put differently, we may have gained knowledge about the environmental information that may be important in the formation of safety perceptions, but there remains a lack in understanding *how* this information is extracted and used. For instance, while there is some theoretical ground for believing that the interpretation of environmental information is a rapid process (e.g., Kaplan & Kaplan, 1989), there are currently no studies that have investigated the temporal aspects of the environmental safety appraisal process. Similarly, while a number of previous authors have proposed that we may psychologically differentiate environmental space based on the relevance of events for our safety (e.g., Goffman, 1971), as of yet it is still unclear whether the acquirement of safety-related environmental information may be adapted accordingly (e.g., that informational cues from the more immediate surroundings are more important as compared to informational cues beyond the immediate surroundings). Furthering our understanding of the way in which safety perceptions come into existence depends critically on investigating these basic processes.

An overview of the current thesis

The general aim of the current thesis is to develop a theoretical understanding of the appraisal process through which physical characteristics of the environment affect the immediate perception of the safety of an environment, with special attention to the role of lighting, regarded as an environmental feature within the proximate environment, in this safety appraisal process.

We are thus 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., Warr, 1990; Foster, Giles-Corti, & Knuiman, 2010), our focus also excludes the visual presence of other people and animals, 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 **Chapter 2**, we present a set of four studies in which participants evaluated a set of nocturnal urban environments with respect to perceived environmental safety, perceived quality of the lighting, and safety-related characteristics of the environment. These studies provide a replication of previous findings from the literature using a wide range of representative environments, and underline the significant contribution of environmental appraisals of safety-related characteristics of the environment to the environmental safety appraisal process. Additionally, we explore whether appraisals of the quality of the lighting may affect environmental safety appraisals directly (e.g., through positive associations with light), or indirectly through an effect on the safety-related environmental characteristics (i.e., prospect, concealment, and entrapment).

In **Chapter 3**, we present two studies that replicate and extend the main findings from Chapter 2, employing multi-level modeling to examine how safety-related environmental characteristics and individual characteristics influence appraisals of environmental safety. More specifically, we systematically examine (a) the contribution of individual (i.e., distal) factors and environmental (i.e., proximate) factors to variance in environmental safety appraisals, (b) individual variability in the susceptibility to safety-related environmental characteristics, and (c) potential interactions between personality characteristics (e.g., trait anxiety) and appraisals of environmental characteristics. Additionally, we investigate whether the effect of biological sex on safety perceptions (e.g., Boomsma & Steg, 2014; Blöbaum & Hunecke, 2005) may be explained by differences in safety-related personality characteristics.

In **Chapter 4**, we examine how much time is needed to extract sufficient (visual) information from the environment to achieve accurate appraisals of environmental safety. In two studies, we measured participants' accuracy in a safety-related dichotomous categorization task under various rapid stimulus presentation times (17ms - 150ms). In addition, the operationalization of our measure of perceived environmental safety as a dichotomous categorization task allows us to assess the robustness of the measures employed in Chapter 2 and Chapter 3, which relied on five-point response category format items to measure perceived environmental safety.

In **Chapter 5**, we extend our understanding of the safety appraisal process by exploring how the masking of environmental information affects environmental safety appraisals and the confidence in these appraisals. More specifically, we examine whether the impact of informational cues is differentiated across environmental space (i.e., is information from certain areas more important than information from other areas within a psychologically differentiated environmental space?). In three studies, we investigate the validity of a new research paradigm for masking environmental information, and whether masking environmental information (from specific stimulus regions) affects participants' evaluations of environmental safety and accuracy in a rapid categorization task. In addition, across all three studies, we explore whether random and targeted masking of safety-related environmental information affects participants' decision confidence (i.e., confidence in evaluation or categorization response).

In **Chapter 6**, we discuss the main findings from the studies presented in the preceding chapters in the light of the broader theoretical framework outlined in the current chapter, consider the potential theoretical and practical implications of the current findings, and offer recommendations for future work.

2

Chapter 2

The role of lighting in environmental safety perception

This chapter is based on:

van Rijswijk, L., & Haans, A. (2015). Illuminating for safety: Investigating the role of lighting in environmental safety perception. *Manuscript submitted for publication*.

van Rijswijk, L. & Haans, A. (2012). Brilliant nights and brilliant lights: How does lighting affect safety feelings? In O. Romice, E. Edgerton & K. Thwaites (Eds.). Meeting abstract: *Proceedings of the 22nd International Association People-Environment Studies Conference (IAPS 22), (pp. 86-87)*. Glasgow: Strathclyde University.

In our modern-day society, public lighting has become quite ubiquitous. Installing or improving public lighting is one of the most often used strategies aimed at (re)designing the built environment in such a way as to reduce the incidence of crime and, ultimately, to improve feelings of safety in public space (Cozens et al., 2005; Crowe, 2000; see Chapter 1).While there is not much debate in the literature about the positive effect of public lighting on subjective experiences of safety (e.g., Welsh & Farrington, 2008; Fotios, Unwin, & Farrall, 2014; Lorenc et al., 2013), there is little to no empirical work that directly investigates the path through which public lighting may affect perceptions of safety (see also Chapter 1). One notable exception may be found in research applying Appleton's (1975) prospect-refuge theory to understand how safety-related environmental characteristics (including lighting) affect people's sense of safety (e.g., Fisher & Nasar, 1992; Boomsma & Steg, 2014; Loewen et al., 1993; Blöbaum & Hunecke, 2005). In Chapter 1 we noted how previous research has successfully identified three important environmental 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, walls, but shadows as well). Lastly, 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 significant role that appraisals of prospect, concealment, and entrapment play in the safety perception process has received ample support from research showing, for example, 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). Defined as the extent to which environments offer physical barriers to escape the environment, Blöbaum and Hunecke (2005) identified entrapment as the most important of the three environmental cues predicting safety appraisal of the environment (see also Boomsma & Steg, 2014).

The role of lighting

We may discern two potential mechanisms through which lighting, regarded as an environmental feature in the proximate environment, may affect the perception of the safety of an environment. First, a unique characteristic of light is that it determines the visibility and atmosphere of other objects and, as such, 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, hamper visibility of escape routes, and may cause dark spots in which people can hide (Nasar & Jones, 1997).

Second, 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., 2014; Loewen et al., 1993; Nasar et al., 1993; Nasar & Jones, 1997). These latter findings suggest that there may exist an intuitive or learned association between lighting and safety, and that the mere presence of lighting may directly affect people's perception of the safety of an environment.

Empirical studies investigating the role of lighting confirm that lighting indeed plays a large role in the safety appraisal process (e.g., Loewen et al., 1993; Blöbaum & Hunecke, 2005; Boomsma & Steg, 2014). However, the results from these studies simultaneously highlight the complexity that characterizes the relationship between lighting and other physical characteristics of the proximate environment. For example, Loewen and colleagues (1993) found light to be the most important factor, and reported that the effect of prospect and entrapment on perceived safety was less pronounced in night-time as compared to day-time environments. In contrast, Blöbaum and Hunecke (2005), considering solely night-time environments, found entrapment to be the most important determinant of perceived safety, and identified an opposite interaction between lighting and entrapment, with entrapment having a more pronounced effect under insufficient lighting conditions.

Most of these studies, while acknowledging the complexity of the interaction between lighting and other environmental characteristics, seem to provide evidence for the existence of an independent, and thus direct, effect of lighting on safety perceptions. However, the operationalization of lighting in these studies does raise questions about whether such an interpretation of the results is warranted. Typically, the design employed by these studies is one in which participants rate the safety of a selection of environments that, based on an evaluation using (expert) judges, differ systematically in illumination levels, prospect, concealment, and entrapment. Such a factorial approach, in which lighting is operationalized as an independent factor on the same level as other safety-related environmental characteristics, assumes that each of the factors in the design is manipulated independently. The artificial untying (Brunswik, 1956) of variables that tend to covary naturally and thus cannot be separated easily in reality significantly reduces the representativeness of the experimental design, and likely poses a threat to the interpretation of any independent and interaction effects found in these studies. Furthermore, the results of studies employing factorial approaches may easily be influenced by arbitrarily defined intervals of the factors in the design. For example, given that Loewen and colleagues (1993) compared the effect of a large interval in light level (i.e., day-time and night-time scenes) with potentially less significant intervals in the levels of prospect and entrapment, it is not very surprising that their results identified light as the most important factor influencing perceived safety.

Ideally, investigating independent effects of lighting requires a comparison of different levels of lighting within the same environment. Moreover, we need to take into account the potential effect that lighting may have on other environmental characteristics if we are serious about investigating the path through which lighting affects people's safety appraisals. Unfortunately, studies investigating how light levels affect appraisals of prospect, concealment, and entrapment remain rare. One such study, in which lighting distributions were manipulated on an outdoor test bed, suggests that the effect of lighting on perceived safety may indeed be mediated, at least partially, by changes in the environment's prospect, concealment, and entrapment (Haans & de Kort, 2012). These results provide preliminary evidence for the existence of an indirect effect of lighting on safety perceptions.

A number of more general issues may be raised with respect to the methodology employed by the majority of the studies investigating the role of safety-related environmental characteristics (including lighting) in the safety appraisal process. As noted before, most of the studies employ a methodology in which the researchers pre-select the environments to be evaluated by participants. Typically, the focus is on one specific type of environment (e.g., a university campus) and the researchers sample a number of areas that represent a range of different configurations of safety-related environmental characteristics (e.g., environments exhibiting a high level of prospect and low levels of concealment and entrapment). One potential drawback of this approach is that the pre-selection of environments that exhibit certain configurations of lighting, prospect, concealment, and entrapment reduces the representativeness of the findings, possibly exaggerating the naturally occurring relationships between these environmental cues and perceptions of environmental safety. This exaggeration may be amplified still by the common practice of instructing participants to evaluate both the safety-related environmental characteristics and the safety of an environment in one session. Furthermore, the observed relationships in such a limited range of environments may not hold when considering the vastly wider range of environments that people find themselves in every day. To increase the generalizability of the various findings in the field, we need to extend the range of environments that we consider in our experiments, for example through the sampling of environments that more accurately reflect people's everyday experience (e.g., Brunswik, 1956).

Research aims

In the current chapter, we investigate how safety-related environmental characteristics (i.e., lighting, prospect, concealment, and entrapment) affect people's appraisal of environmental safety. More specifically, our main focus is understanding the role of lighting in the safety perception process. In Study 2.1, employing a large range of environments that more accurately reflect the ecological niche of our participants, we test the robustness of the prospect-refuge approach to understanding environmental safety perceptions. In Study 2.2, we examine the role of appraisals of lighting as they relate to appraisals of prospect, concealment, and entrapment, and perceptions of environmental safety. More specifically, we test whether the effect of lighting on perceptions of environmental safety is mediated by appraisals of the safety-related characteristics (see *Figure 2.1*). In Study 2.3 and Study 2.4, we complement the correlational approach used in Study 2.2 to understand the role of lighting by experimentally manipulating ambient lighting level and physical characteristics of simulated environments (a- and b-paths in *Figure 2.1* respectively).

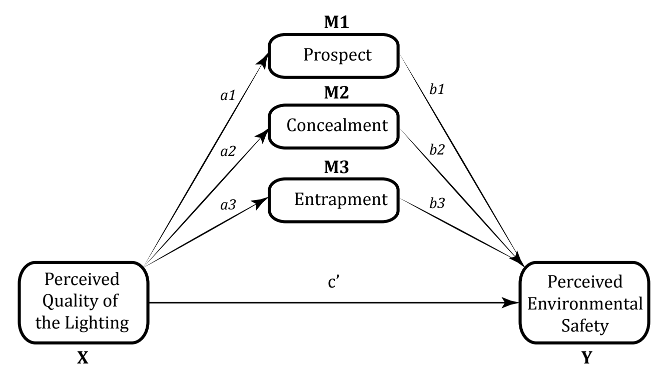

Figure 2.1. The mediation model underlying the studies presented in the current chapter.

Study 2.1

In the first study, two groups of participants independently evaluated a set of 100 photographs of nocturnal urban environments either on safety-related environmental characteristics (i.e., prospect, concealment, and entrapment) or on perceived environmental safety. The validity of using photographs to investigate evaluations of environmental qualities is supported by previous research (e.g., Stamps, 1990; 1993; 2010). Based on the methodology for integrative reviews of findings from multiple studies proposed by Hedges and Olkin (1985), Stamps has performed several meta-analyses of studies comparing participant responses obtained on-site and from photographs and other virtual simulations in the domain of environmental perception. The studies considered in these reviews include a range of responses (e.g., safety, preferences, scenic quality) as well as different type of measures (e.g., Likert-type rating scales, semantic differential rating scales). Results from these meta-analyses consistently indicate that there is a high correlation between evaluation responses obtained on-site and evaluation responses obtained from both static color photographs and dynamic simulations (see *Table 2.1*), suggesting that static color photographs and dynamic virtual representations (e.g., video, dynamic virtual environments) are valid means for examining perceptions of environmental qualities.

The aim of this study was to provide a test of the robustness of the findings from studies applying the prospect-refuge framework to the investigation of environmental safety perception, by using a wide variety of environments people may encounter on a daily basis.

Based on the findings from the literature (e.g., Fisher & Nasar, 1992; Nasar et al., 1993), we expected that appraisals of prospect would be positively associated with perceived environmental safety, and that appraisals of concealment and entrapment would be negatively associated with perceived environmental safety.

Reference	Comparison	N	r	LLCI	ULCI
Stamps (1990)	on-site / static photographs	152	.86	.80	.90
Stamps (1993)	on-site / static photographs	185	.83	.79	.87
Stamps (2010)	on-site / static photographs	205	.86	.84	.90
Stamps (2010)	on-site / dynamic simulation	171	.83	.78	.87

Table 2.1. Results of meta-analytic reviews, showing type of comparisons, total number of stimuli (N), overall correlation (r), and lower level (LLCI) and upper level (ULCI) 95% confidence intervals.

Method

Participants and design. We employed a within-subjects design in which participants evaluated a set of 100 photographs depicting nocturnal urban environments. The dependent variables were perceived environmental safety and appraisals of 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). The participants were registered in the Eindhoven University of Technology's J.F. Schouten participant database and responded to an invitation to participate in our study. Participants required approximately one hour to complete our study and received €10,- as compensation for their participation.

Figure 2.2. Examples from our set of 100 photographs of nocturnal urban environments.

Materials and measures. The stimulus set used in the current study comprised 100 high-resolution photographs of nocturnal urban environments which were shot in the summer of 2011 between 4 AM and 6 AM in the villages of Best and Geldrop in the Netherlands.[1] Weather conditions during these two days were fair. The set of photographs sampled environments that urban residents in these areas encounter on a daily basis, but were devoid of other people or animals, thus focusing on the physical environment and controlling for influences that may be attributed to the visual presence of others (see *Figure 2.2* for some examples of the type of environments represented in our stimulus set). The included sites were more or less randomly selected until a total number of 100 sites were collected. A

1 The full set of stimuli can be downloaded from http://www.antalhaans.nl/files/photoset.zip. The zip file also contains stimulus-level data from all studies presented in the current thesis.

Nikon D3100 photocamera mounted on a tripod was used to shoot the photographs. All photographs were shot in 14.2 megapixels (4608 x 3072 pixels; ISO 200) without flash. There was no additional software editing of the photographs before use in the experiments.

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 five-point response category 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 Appendix B. We calculated the average of the three items for each measure and used these aggregate scores in our analyses ($\alpha_{\text{environmental safety}} = .91$, $\alpha_{\text{prospect}} = .95$, $\alpha_{\text{concealment}} = .69$, $\alpha_{\text{entrapment}} = .79$).

Procedure. The participant was welcomed into the lab, instructed to complete an informed consent form, and directed to one of eight available 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 50cm in front of a 19" color calibrated LCD monitor screen running at a 1600 pixels by 1200 pixels resolution and a 60Hz 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 large version of the stimulus was presented on the monitor screen for five seconds, after which the participant responded to questions about the stimulus. While the participant answered the questions, a smaller version of the stimulus was present on the screen. One group of participants ($N = 15$) responded to the questions of our environmental safety measure, while a second group of participants ($N = 16$) responded to the questions of the prospect, concealment, and entrapment measures. Participants were randomly assigned to one of these two groups. After completing the questions for all the stimuli, the participant responded to three demographic questions about sex, age, and current residence.

Results and discussion

All of the reported analyses are performed on the aggregate measure scores for each stimulus across all participants. Descriptives for the measures of our dependent variables are presented in *Table 2.2*. We first examined correlations between the measure of environmental safety and the measures of the safety-related environmental characteristics (see *Table 2.3*). 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 the ratings of perceived environmental safety and the safety-related environmental characteristics are obtained independently from each other. Next, we examined the correlations among the measures of the safety-related characteristics (see *Table 2.3*). Prospect was negatively correlated with concealment ($r = -.83$, $p < .001$) and entrapment ($r = -.72$, $p < .001$), and concealment was positively correlated with entrapment ($r = .73$, $p < .001$).

	M	SD	Min	Max
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

Table 2.2. Descriptives for the measures of environmental safety, prospect, concealment, and entrapment in Study 2.1.

	Safety	Prospect	Concealment	Entrapment
Safety	-			
Prospect	.71***	-		
Concealment	-.65***	-.83***	-	
Entrapment	-.85***	-.73***	.73***	-

Note. *** $p < .001$

Table 2.3. Correlations between measures of environmental safety, prospect, concealment, and entrapment in Study 2.1.

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 $R^2_{\text{adj}} = .74$. As expected, appraisals of both entrapment and prospect significantly predicted perceived environmental safety (see *Table 2.4*). Concealment was not found to predict perceived environmental safety to a significant extent (see *Table 2.4)*.

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; Tonidandel & LeBreton, 2011; Graham, 2003). 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 2.3*).

Hence, we employed the *rego*[2] package, available for Stata, 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 to appraisals of prospect (see right-hand side of *Table 2.4*). 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.

	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	-.75	-9.49	< .001	55.32	43.64	67.00
Observations				100		
Full model R^2				.75		

Table 2.4. OLS multiple regression results with the decomposition of R^2 (in % of total R^2). Lower level (LLCI) and upper level (ULCI) confidence intervals based on bootstrapping with 5000 resamples.

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 = .86, SD_r = .033, M_{R2} = .74).

Across our large sample of representative environments, our regression model, predicting perceived environmental safety from appraisals of prospect, concealment, and entrapment accounted for approximately 75% of the variance in safety judgments. The model was found to be robust across 100 split sample validations. As expected, both prospect and entrapment were identified as significant predictors of perceived environmental safety. Moreover, our

2 The *rego* package for Stata is available at http://www.uni-leipzig.de/~rego/ (Huettner & Sunder, 2012)

findings are in line with previous findings indicating that appraisals of entrapment are most strongly associated with perceived environmental safety (Blöbaum & Hunecke, 2005). In contrast to previous findings, concealment was not found to make a significant contribution to perceived environmental safety in our model. However, the individual effects identified in the multiple regression analysis were biased by the high multicollinearity among the predictor variables, and the variance decomposition analysis revealed that appraisals of concealment contributed approximately as much to the overall variance in environmental safety appraisals as appraisals of prospect. Our results thus confirm previous findings from the perceived safety literature and provide evidence for the importance of appraisals of safety-related environmental characteristics in the safety perception process. After this initial step, we extended our investigation to the role of lighting in the safety appraisal process by including participants' appraisals of the quality of the lighting in our regression model.

Study 2.2

The general aim of Study 2.2 was to examine the path through which appraisals of the quality of the lighting in an environment affect people's perception of the safety of an environment. We employed a similar design as Study 2.1 and asked participants to evaluate the quality of the lighting of the set of 100 stimuli used in the previous study. Following previous findings from the literature, we expected to find that appraisals of the quality of the lighting would be positively associated with the appraisals of environmental safety obtained in Study 2.1. More importantly, based on the findings presented by Haans and de Kort (2012), we expected that this effect of perceived quality of the lighting on perceived environmental safety would, at least partially, be mediated by the effect of perceived quality of the lighting on the safety-related environmental characteristics (i.e., 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). The participants were registered in the Eindhoven University of Technology's J.F. Schouten participant database and responded to an invitation to participate in our study. Participants required approximately one hour to complete our study and received €10,- as compensation for their participation.

Materials and measures. We used the same stimulus set of 100 photographs of nocturnal urban environments used in Study 2.1. Perceived quality of the lighting was measured using six five-point response category 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 Appendix B. We calculated the average of the six items for each stimulus and used this aggregate score in our analyses (α = .87).[3]

Procedure. The procedure and conditions of Study 2.2 were analogous to those of Study 2.1, 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 2.1. Descriptives for the measure of perceived quality of the lighting are presented in *Table 2.5*. 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 2.1 (see *Table 2.6*). 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).

	M	SD	Min	Max
Perceived Quality of the Lighting	2.91	.69	1.26	4.53

Table 2.5. Descriptives for the measure of perceived environmental safety in Study 2.2.

	Safety	Prospect	Concealment	Entrapment
Perceived Quality of the Lighting	.47***	.76***	-.48***	-.49***

*Note. *** p < .001*

Table 2.6. Correlations between the measures of perceived quality of the lighting in Study 2.2 and the measures environmental safety, prospect, concealment, and entrapment in Study 2.1.

3 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.

To test whether appraisals of the quality of the lighting predicted appraisals of environmental safety, we performed a 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_{adj} = .21. As expected, perceived quality of the lighting was significantly related to perceived environmental safety (β = .48, t = 5.22, p < .001). The regression model was moderately robust across 100 split sample validations (M_r = .48, SD_r = .079, M_{R2} = .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_{adj} = .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_{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_{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.

While our results show that appraisals of the quality of lighting are indeed associated with perceived environmental safety, the lack of predictive power over the safety-related environmental characteristics and the medium to high correlations between perceived quality of the lighting and the safety-related environmental characteristics suggest that this association may be mediated by changes in appraisals of prospect, concealment, and entrapment. We used the bootstrapping method for multiple mediation by Preacher and Hayes (2004; 2008) to test whether the effect of perceived quality of the lighting on perceived environmental safety was mediated by appraisals of the safety-related environmental characteristics. See *Figure 2.1* for a representation of the mediation model we tested, and *Table 2.7* for a summary of the results of our mediation analysis.

Independent variable	Total effect	Direct effect	Mediator	a	b	Indirect effect	LLCI	ULCI
Perceived Quality of the Lighting	.476***	-.127	Prospect	.787***	.410***	.322	.103	.593
			Concealment	-.381***	.241	-.092	-.240	.020
			Entrapment	-.447***	-.833***	.372	.214	.574

*Note. Reported confidence intervals are bias corrected. *** p < .001*

Table 2.7. Summary of mediation analysis results. 95% confidence intervals based on bootstrapping with 5000 resamples.

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). Our results also confirm the multiple regression analyses, showing that perceived quality of the lighting (total effect), and prospect and entrapment (see *b*s) 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 both the indirect effect of prospect and entrapment were significant. The indirect effect of concealment was not significant. Importantly, our results show that if we account for the relation between perceived quality of the lighting and appraisals of the safety-related environmental characteristics, the effect of perceived quality of the lighting on perceived environmental safety (direct effect) is no longer significant, suggesting that this effect is fully mediated by changes in appraisals of prospect and entrapment.

In sum, our results show that while perceived quality of the lighting of environments significantly affects the perceived environmental safety of those environments, this effect can be fully accounted for by changes 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 the effect of prospect and entrapment.

However, these results should be considered with some caution, as the correlational design of the current study is less suitable for making inferences about the causal chains underlying mediation processes and thus does not necessarily provide the strongest evidence for the proposed mediation process (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 appraisals of lighting. Therefore, the strength of our claim would benefit from additional experimental studies employing an experimental-causal-chain design, showing 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 2.1*), and manipulation of prospect, concealment, and entrapment leads to changes in perceived environmental safety (i.e., the *b*-path in our mediation model, see *Figure 2.1*). Thus, the following two studies we present were aimed to extend the evidence for the indirect effect of lighting on safety perceptions through appraisals of safety-related environmental characteristics, manipulating both lighting levels (Study 2.3), as well as safety-related environmental characteristics (Study 2.4).

Study 2.3

Study 2.3 was designed to test the *a*-path of our mediation model (see *Figure 2.1*). We created three different virtual environments, exhibiting different configurations of safety-related environmental characteristics, and manipulated the ambient lighting level in these environments. We then collected participants' evaluations of prospect, concealment, and entrapment for each of the virtual environments under different ambient lighting levels. We expected that increases in ambient lighting levels would be associated with an increase in appraisals of prospect and a decrease in appraisals of concealment and entrapment.

Method

Participants and design. We employed a mixed design with type of environment as within-subjects factor, ambient lighting level as between-subjects factors, and ratings of prospect, concealment, and entrapment as dependent variables. Three groups of participants evaluated the level of prospect, concealment, and entrapment of three computer-simulated environments under different ambient lighting conditions. The sample comprised 90 participants (58 males and 31 females, M_{age} = 23.64, SD_{age} = 6.21, age range = 18 - 46 years). We failed to record demographics for one participant due to a software malfunction. Participants were recruited on the campus of the Eindhoven University of Technology. The experiment required approximately five minutes to be completed and participants received no compensation for their participation.

Materials and measures. We simulated three different environments using the AutoCAD and Autodesk 3ds Max Design 2012 software packages (see *Figure 2.3*). The three environments were created in such a way as to reflect a natural variation of levels of prospect, concealment, and entrapment. The first environment was a footpath enclosed by dense trees (*Figure 2.3a*). This environment was designed to exhibit a low level of prospect, a high level of concealment, and an intermediate to high level of entrapment. The second environment was a tunnel (*Figure 2.3b*), designed to exhibit intermediate to high levels of prospect and entrapment, and a low level of concealment. The last environment was a street in a residential urban area (*Figure 2.3c*). This environment was designed to exhibit an intermediate to high level of prospect, and low levels of concealment and entrapment.

From each of the three base environments, two additional environments were rendered with increased levels of ambient lighting. The base environments included an omni light modifier that controlled the ambient lighting in the simulated environment. For the first increase in ambient light level, we set the intensity multiplier of the omni light modifier to 0.2, and for the second increase in ambient light level, we set the intensity multiplier to 0.4. With the two extra renderings for each environment, the total number of stimuli used in the present experiment was nine (see Appendix A).

a b c

Figure 2.3. The three simulated environments used in Study 2.3 and Study 2.4; footpath (a), tunnel (b), and residential street (c).

	Overall			Baseline (OM = 0)		
	Footpath	Tunnel	Street	Footpath	Tunnel	Street
Prospect	2.11 (.80)	3.92 (1.02)	3.84 (.91)	2.04 (.79)	3.68 (.91)	3.33 (1.09)
Concealment	4.10 (.76)	2.31 (.88)	2.69 (.88)	4.08 (.73)	2.21 (1.06)	2.97 (.94)
Entrapment	3.13 (.89)	3.79 (.83)	2.37 (.79)	3.21 (.80)	3.70 (.91)	2.70 (.88)
	Intermediate level (OM = 0.2)			High level (OM = 0.4)		
	Footpath	Tunnel	Street	Footpath	Tunnel	Street
Prospect	2.06 (.77)	3.86 (1.03)	4.00 (.72)	2.23 (.93)	4.20 (1.06)	4.15 (.68)
Concealment	4.19 (.82)	2.39 (.85)	2.60 (.84)	4.04 (.73)	2.33 (.73)	2.53 (.84)
Entrapment	2.97 (.93)	3.91 (.83)	2.28 (.66)	3.11 (.92)	3.74 (.76)	2.15 (.74)

Note. Standard deviations between brackets. OM = Omnilight modifier

Table 2.8. Means and standard deviations for the measures of prospect, concealment, and entrapment for each of the three simulated environments across all lighting level conditions.

To measure the safety-related environmental characteristics we used the same measures for prospect, concealment, and entrapment we used in Study 2.1. For each participant, we calculated the average of the three items for each stimulus and used this aggregate score in our analyses ($\alpha_{prospect}$ = .93, $\alpha_{concealment}$ = .75, $\alpha_{entrapment}$ = .75).

Procedure. The procedure of Study 2.3 closely followed the procedure of Study 2.1 and lab conditions were comparable to those of Study 2.1. One group of participants (N = 29) viewed the three baseline simulated environments, a second group (N = 30) viewed the simulated environments with an intermediate increase in ambient lighting level (i.e., an omnilight modifier of 0.2 intensity), and the last group (N = 31) viewed the simulated environments with a high increase in ambient lighting level (i.e., an omnilight modifier of 0.4 intensity). Participants were randomly assigned to one of the three ambient lighting conditions. The stimuli were presented in random order. For each stimulus, the participant responded to the questions of the prospect, concealment, and entrapment measures. After finishing the questions for all the stimuli, the participant responded to two demographic questions about sex and age.

Results and discussion

The effect of our ambient lighting manipulation was analyzed with a mixed-design ANOVA for each safety-related environmental characteristic separately (see *Table 2.8* for means and standard deviations for each lighting condition). Type of environment was included as a control variable in these analyses. Potential main effects on the level of the stimulus, however, served primarily as a manipulation check to see whether we succeeded in creating environments that significantly differed from each other in their configuration of the safety-related environmental characteristics. These manipulation checks are reported prior to the main analyses (see *Table 2.8* for the sample means).

Prospect. We conducted a mixed-design ANOVA with type of environment (rural footpath, tunnel, residential street) as a within-subjects factor, ambient lighting level (baseline, 0.2 intensity, and 0.4 intensity) as a between-subjects factor, and ratings of prospect as the dependent variable.

Manipulation check. The results indicated a main effect of type of environment on the rating of prospect with $F(2,174) = 141.65$, $p < .001$, and $\eta_p^2 = .62$. As expected, post hoc tests using a Bonferroni correction revealed that prospect was rated lower for the rural footpath environment as compared to the tunnel ($M_{difference} = -1.80$, $SD = .12$, $p < .001$) and residential street ($M_{difference} = -1.72$, $SD = .11$, $p < .001$) environments. There was no significant difference between the rating of prospect for the tunnel and the residential street environments ($M_{difference} = .09$, $SD = .13$, $p < .001$).

Main analysis. With respect to our ambient lighting manipulation, the results showed a main effect of ambient lighting level on prospect with $F(2,87) = 5.48$, $p = .006$, and $\eta_p^2 = .112$. Post hoc tests using Tukey's HSD indicated that prospect ratings were higher in the 0.4 intensity ambient lighting condition as compared to the baseline ambient lighting condition ($p = .004$). Prospect ratings did not differ significantly between baseline and the 0.2 intensity ambient lighting conditions ($p = .163$), and between 0.2 and 0.4 intensity ambient lighting conditions ($p = .312$). As expected, however, we found a modest linear trend ($C = .508$, $F(1,87) = 3.86$, $p = .001$, $\eta_p^2 = .11$), such that increases in ambient lighting level led to an increase in ratings of prospect. The results showed no significant interaction between ambient lighting level and type of environment with $F(4,174) = 1.13$, $p = .147$, and $\eta_p^2 = .04$.

Concealment. We conducted a mixed-design ANOVA with type of environment as a within-subjects factor, ambient lighting level as a between-subjects factor, and ratings of concealment as the dependent variable.

Manipulation check. The results indicated a main effect of type of environment on the rating of concealment with $F(2,174) = 113.20, p < .001$, and $\eta_p^2 = .57$. As expected, post hoc tests using a Bonferroni correction revealed that concealment was rated higher for the rural footpath environment as compared to the tunnel ($M_{difference} = 1.79$, $SD = .12$, $p < .001$) and residential street ($M_{difference} = 1.41$, $SD = .13$, $p < .001$) environments. Furthermore, the post hoc tests indicated that concealment was rated somewhat higher in the residential street environment as compared to the tunnel environment ($M_{difference} = .39$, $SD = .13$, $p = .008$).

Main analysis. The results revealed no main effect of ambient lighting level on concealment with $F(2,87) = .48$, $p = .622$, and $\eta_p^2 = .01$. Moreover, against our expectations, our test for a linear decrease in concealment ratings as ambient lighting levels increase showed no significant linear trend ($C = -.117$, $F(1,87) = .85$, $p = .359$, $\eta_p^2 = .01$). Thus, these results suggest that concealment ratings of the environments were not affected by our ambient lighting manipulation. The results showed no significant interaction between ambient lighting level and type of environment with $F(4,174) = 1.22$, $p = .306$, and $\eta_p^2 = .03$.

Entrapment. We conducted a mixed-design ANOVA with type of environment as a within-subjects factor, ambient lighting level as a between-subjects factor, and ratings of entrapment as the dependent variable.

Manipulation check. The results indicated a main effect of type of environment on the rating of entrapment with $F(2,174) = 70.64$, $p < .001$, and $\eta_p^2 = .45$. As expected, post hoc tests using a Bonferroni correction revealed that entrapment was rated higher for the tunnel environment as compared to the rural footpath ($M_{difference} = .65$, $SD = .12$, $p < .001$) and residential street ($M_{difference} = 1.41$, $SD = .12$, $p < .001$) environments. Furthermore, the post hoc tests indicated that entrapment was rated higher in the rural footpath environment as compared to the residential street environment ($M_{difference} = .76$, $SD = .12$, $p < .001$).

Main analysis. The results revealed no main effect of ambient lighting level on entrapment with $F(2,87) = 1.77$, $p = .147$, and $\eta_p^2 = .04$. Our test for a linear decrease in entrapment ratings as ambient lighting levels increase showed a marginally significant linear trend ($C = -.238$, $F(1,87) = 3.21$, $p = .077$, $\eta_p^2 = .04$). These results suggest that entrapment ratings of the environments were only minimally affected by our ambient lighting manipulation. The results showed no significant interaction between ambient lighting level and type of environment with $F(4,174) = 1.87$, $p = .118$, and $\eta_p^2 = .04$.

In sum, we tested whether our manipulation of ambient lighting level affected ratings of prospect, concealment, and entrapment. As expected, our results revealed a positive linear trend for appraisals of prospect, where increases in ambient lighting level were associated with increases in the evaluation of prospect in the environment. However, we did not find similar linear trends for the effect of ambient lighting level on evaluations of concealment and entrapment. In fact, our lighting manipulation seems to have only marginally affected participants' appraisals of the safety-related environmental characteristics. Although limited to appraisals of prospect, the results do provide evidence that the manipulation of lighting levels leads to changes in judgments of safety-related environmental characteristics.

Study 2.4

The aim of Study 2.4 was to experimentally test the *b*-path of our mediation model (see *Figure 2.1*). We used the three different virtual environments with an intermediate ambient lighting level (i.e., omnilight modifier 0.2) described in the previous study, and collected participants' evaluations of the safety of these environments. Based on the evaluations of prospect, concealment, and entrapment obtained in Study 2.3 (see 'Intermediate level' section of *Table 2.8*), we expected that the residential street environment, exhibiting a relatively high level of prospect, and low levels of concealment and entrapment, would be evaluated as the most safe environment. Furthermore, we expected that the rural footpath environment, exhibiting a relatively low level of prospect, and intermediate to high levels of concealment and entrapment, would be evaluated as the least safe environment. Given that the tunnel environment was evaluated as exhibiting both a high level of prospect as well as a high level of entrapment, we expected the tunnel environment to fall in between the rural footpath and the residential street.

Method

Participants and design. We employed a within-subjects design in which participants responded to questions about perceived environmental safety for three computer-simulated environments. The sample comprised 30 participants (23 males and 7 females, $M_{age} = 20.60$, $SD_{age} = 2.53$, age range = 18 - 27 years). Participants were recruited on the campus of the Eindhoven University of Technology. The experiment required approximately three minutes to be completed and participants received no compensation for their participation.

Materials and measures. The stimuli used in Study 2.4 were the three different computer-simulated environments with 0.2 ambient lighting intensity used in Study 2.3 (see Appendix A). To measure perceived environmental safety we used the same three-item measure we used in Study 2.1 (see Appendix B). For each participant, we calculated the average of the three items of this measure and used this aggregate score in our analyses ($\alpha = .84$).

Procedure. The general procedure and lab conditions of Study 2.4 were similar to those of the previous studies. Participants viewed the three stimuli in random order and responded to the questions of the perceived environmental safety measure. After finishing the questions for all the stimuli, the participant responded to two demographic questions about sex and age.

Results and discussion

We conducted a one-way repeated measures ANOVA with type of environment (i.e., rural footpath, tunnel, residential street) as within-subjects factor, and perceived environmental safety as the dependent variable. As expected, we found a main effect of type of environment on ratings of perceived environmental safety with $F(2,87) = 18.70$, $p < .001$, and $\eta_p^2 = .45$. Posthoc analyses using Tukey's HSD indicated that perceived environmental safety ratings were higher for the residential street as compared to the rural footpath ($p < .001$) and the tunnel ($p < .001$). However, perceived environmental safety did not differ significantly between the rural footpath and the tunnel ($p = .275$). In line with the results from Study 2.1, this latter finding suggests that appraisals of the level of entrapment have the strongest influence on appraisals of environmental safety, and that positive evaluations of prospect may be outweighed by negative evaluations of entrapment. Nonetheless, these results provide evidence that the manipulation of safety-related environmental characteristics in virtual environments lead to predictable changes in perceptions of the safety of these environments.

General discussion

Public lighting is commonly associated with a positive effect on the experience of safety in public space. Yet, little is known about the psychological processes through which lighting may exert its influence on people's safety perceptions. Applying Appleton's prospect-refuge framework, we investigated the role of lighting in environmental safety perception using a wide range of stimuli depicting nocturnal urban environments. Across four studies, we tested the idea that lighting influences appraisals of environmental safety through its effect on appraisals of safety-related environmental characteristics (i.e., prospect, concealment, and entrapment).

Safety-related environmental characteristics and perceived environmental safety

Our findings are largely in line with previous findings highlighting the important role that appraisals of prospect, concealment, and entrapment play in the safety appraisal process (e.g., Fisher & Nasar, 1992; Blöbaum & Hunecke, 2005). The results from Study 2.1 show a high correlation between appraisals of safety-related environmental characteristics and judgments of environmental safety. More importantly, our model testing 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 the environments in our stimulus set.

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, with higher levels of entrapment 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, such that environments offering higher levels of prospect, as compared to environments offering lower levels of prospect, were associated with higher judgments of perceived environmental safety. These findings were replicated in Study 2.4, in which we manipulated safety-related environmental characteristics in three virtual environments.

In contrast to previous findings (e.g., Fisher & Nasar, 1992; Blöbaum & Hunecke, 2005; Haans & de Kort, 2012), however, the results from both Study 2.1, using photographs of real environments as stimuli, and Study 2.4, using simulated environments, did not show the expected association between appraisals of concealment and judgments of safety. Some of the discrepancies between our results and the typical findings in the literature may stem from differences in the labeling of environmental characteristics. For example, Blöbaum and Hunecke (2005) measured the perceived level of concealment in their experimental settings by asking about the amount of overview the environments offers, which is more or less similar to how we measure prospect in Study 2.1 and Study 2.4. Thus, if we disregard the specific labels applied to similar environmental characteristics, our results are in fact highly similar to the findings presented by Blöbaum and Hunecke. However, differences in the labeling of environmental characteristics cannot account for all findings showing an effect of concealment, as other studies do use comparable operationalizations of concealment (e.g., Haans & de Kort, 2012; Nasar & Jones, 1997). One potential explanation for the lack of an effect of concealment in our studies may be that in virtually all of the other studies that report an effect of concealment, participants evaluated environmental safety and safety-related characteristics of the environment in situ, as opposed to the lab setting used in our studies. It may well be that the extent to which environments offer places to hide for potential offenders becomes more salient, and thus more important, when one finds oneself in a real environment at night.

Barring these considerations, the results from Study 2.1 and Study 2.4 extend the literature by showing the prominence of safety-related environmental characteristics in the safety appraisal process using a large set of stimuli reflecting a more diverse range of environments that people may encounter on a daily basis. The combination of this variety of environments and the adoption of a methodology that separates evaluations of environmental characteristics and environmental safety improves the generalizability of previous findings from the literature and provides more solid support for models of perceived environmental safety based on the safety-related environmental characteristics.

Lighting and the safety-related environmental characteristics

Previous findings from the literature suggest that lighting, regarded as an environmental feature in the proximate environment, may affect the safety appraisal process directly, influencing people's perception of safety (e.g., Loewen et al., 1993; Blöbaum & Hunecke, 2005; Haans & de Kort, 2012), and/or indirectly, through lighting's effect on appraisals of other safety-related environmental characteristics (Haans & de Kort, 2012). By means of two different methodological approaches, Study 2.2 and Study 2.3 were designed to test the hypothesis that lighting affects environmental safety perceptions through its effect on environmental appraisals of prospect, concealment, and entrapment (i.e., the effect of lighting on perceived environmental safety is mediated by appraisals of the safety-related characteristics; see *Figure 2.1*).

In Study 2.2, participants evaluated the quality of the lighting of the environments that comprised the stimulus set used in Study 2.1. Considering these appraisals of lighting in isolation, our results indicated that participants' appraisal of the quality of the lighting significantly predicted variation in perceived environmental safety. However, including appraisals of lighting as an additional predictor in the regression model used in Study 2.1 (including appraisals of prospect, concealment, and entrapment as predictors), revealed that appraisals of lighting did not predict perceived environmental safety beyond appraisals of the safety-related environmental characteristics. Moreover, the results from our mediation analysis showed that the effect of appraisals of lighting on perceived environmental safety was fully mediated by appraisals of the safety-related characteristics. In other words, when we accounted for the effect of the appraisals of lighting on appraisals of prospect, concealment, and entrapment, the effect of lighting on perceived safety was no longer significant. These results thus provide support for the hypothesis that the effect of lighting on perceived environmental safety is mediated by the effect of lighting on appraisals of the safety-related environmental characteristics.

Study 2.3 and Study 2.4 complemented the measured-mediation design used in Study 2.2 with an experimental-causal-chain approach to examining the proposed mediation model (Spencer et al., 2005). In Study 2.3, we experimentally manipulated ambient lighting levels, and tested the effect of this lighting manipulation on appraisals of prospect, concealment, and entrapment (i.e., the *a*-paths specified in the mediation model, see *Figure 2.1*). As expected, increases in ambient lighting level were associated with more positive appraisals of prospect. However, changes in ambient lighting level were not found to impact appraisals of entrapment and concealment. Given that mediation requires that the independent variable affects the proposed mediators, Study 2.3 does not provide convincing support for the notion that lighting affects environmental safety appraisals through appraisals of safety-related environmental characteristics (beyond prospect). However, we may identify some concerns with regard to the manipulation of lighting we employed.

For example, it may well be the case that our specific manipulation of lighting (i.e., increasing the ambient lighting level in a simulated environment) was not realistic enough to impact appraisals of concealment and entrapment. For example, by merely utilizing changes in the ambient lighting level in our simulated environments, our manipulation may have primarily affected visibility (i.e., prospect). Alternatively, our manipulation of ambient lighting levels may not have been sufficiently strong to provide a robust test of the effect of lighting on appraisals of the safety-related environmental characteristics. We manipulated the ambient lighting levels to support the finding from Study 2.2 that the effect of lighting on perceived environmental safety is mediated by appraisals of these environmental characteristics. Yet, the findings of Study 2.2 were based on subjective appraisals of the lighting in the depicted environments, and, while we used the manipulation of ambient lighting levels in Study 2.3 to achieve variation in people's appraisals of the lighting in our simulated environments, we did not perform a formal manipulation check to see whether people indeed evaluated the lighting differently between our three ambient lighting level conditions. The absence of a robust effect of our ambient lighting manipulation may have additionally been a consequence of employing a between-subjects design in which different groups of people evaluated scenes under the three different ambient lighting levels. While we opted for this approach over a within-subjects approach to counter potential demand characteristics in the evaluation of the different lighting levels, such a design may not be the most sensitive when it comes to relatively subtle manipulations and our choice of this specific experimental design may thus partly account for the absence of a robust effect of ambient lighting level on appraisals of the safety-related characteristics. With appropriate attention given to the potential drawbacks of each design, future research could employ different experimental designs that may potentially be more sensitive to test subtle manipulations of (ambient) lighting levels.

In sum, these studies are largely in line with previous findings supporting the hypothesis that lighting affects perceptions of safety through its effect on safety-related environmental appraisals (Haans & de Kort, 2012). Importantly, however, future research employing a stronger and more realistic manipulation of lighting could improve the assessment of the impact of lighting on appraisals of the safety-related environmental characteristics.

Limitations

Some limitations may be identified with respect to the studies presented in this chapter. First, an alternative explanation for the differences in perceived environmental safety we found between the simulated environments is that we did not only manipulate the physical characteristics of these environments, but also the general environmental context (e.g., the way in which these type of environments are typically used). As a consequence, participants may, for example, have evaluated the residential street as more safe than the rural footpath and tunnel because of preconceptions about how safe one would feel traveling through such different environments in real life. To disqualify such an alternative interpretation, future research may aim to manipulate the safety-related environmental characteristics in more similar environmental contexts. Another limitation regarding the use of the simulated environments in Study 2.3 and Study 2.4 is that we only tested three different types of environments – environments that we specifically manipulated to express certain configuration of the safety-related environmental characteristics. In Chapter 1, we have outlined the argument that the use of non-representative sets of environments may potentially constrain the correct interpretation of results and that findings from studies employing such limited sets should not simply be generalized to a more inclusive set of environments that people may encounter on a day-to-day basis. To further validate the findings based on the three simulations, future research may aim to replicate or extend the current findings employing a larger, more representative set of (simulated) environments.

Second, the controlled lab setting in which our studies were performed, while certainly advantageous for testing the robustness of a prospect-refuge approach to safety perceptions using the large range of environment in our stimulus set, 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 on the university campus will probably not have put them in the same emotional state as actually walking alone in public space at night. As discussed above, such a discrepancy between making a calm, perceptual judgment of the safety of an environment, and making an appraisal of safety in situ, may account for the lack of an effect of appraisals of concealment on safety. Furthermore, with respect to investigating a potential effect of lighting, our manipulation of ambient lighting levels in a simulated environment presented as stimulus on a computer screen in the lab may produce different outcomes than the actual experience of different lighting conditions. Although there is ample research showing the effects of the safety-related environmental characteristics on safety perceptions in real-world settings, future research into the effect of lighting on appraisals of these environmental characteristics may be aimed at replicating our findings in more immersive virtual settings or in real-world settings.

Third, we have stressed the importance of testing hypotheses about the effect of environmental characteristics (including lighting) on people's sense of safety in a wider range of environments that people encounter on a daily basis. Although we believe that the large variety in the selection of environments used in Study 2.1 and Study 2.2 represent a significant improvement over the limited set of locations commonly used in this type of 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 selecting environments, for inclusion in a set of photographs or for real-world experimentation, using more thorough random selection methods.

Finally, by aggregating over participants' individual responses, analyzing our data on the level of the stimulus (i.e., photographs or simulated environments), 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 people are more susceptible to safety-related environmental information, such that appraisals of prospect, concealment, and entrapment are more heavily weighed when forming a judgment about the safety of an environment. We explore this possibility in Chapter 3 in which we employ multi-level modeling to examine how both individual-level and environment-level characteristics affect perceptions of environmental safety.

Conclusion

The current set of studies provides evidence for the idea that lighting affects environmental safety perceptions through its effect on appraisals of safety-related environmental characteristics (i.e., prospect, concealment, and entrapment). Additionally, we replicate previous findings that highlight the important role of appraisals of safety-related environmental characteristics in the safety appraisal process, and extend the literature by demonstrating that the association between safety-related environmental appraisals and environmental safety perceptions are also found using a large set of environments that people encounter on a daily basis.

Chapter 3

Individual susceptibility to safety-related environmental characteristics

3

This chapter is based on:

van Rijswijk, L., Rooks, G., & Haans, A. (in press). Safety in the eye of the beholder: Individual susceptibility to safety-related characteristics of nocturnal urban scenes. *Journal of Environmental Psychology*.

The main aim of the current thesis is to develop a theoretical understanding of the appraisal process through which physical characteristics of the environment affect the immediate perception of the safety of an environment. To this end, we adopted a functionalist approach to environmental perception, emphasizing the importance of selecting and weighing information from the immediate environment to achieve accurate appraisals of environmental qualities (e.g., Brunswik, 1952; Kaplan & Kaplan, 1989; see Chapter 1). Based on Appleton's (1975) prospect-refuge theory, we characterized the proximate cues framework which identifies three potentially relevant environmental characteristics that may influence the appraisal of environmental safety (e.g., Fisher & Nasar, 1992; Nasar et al., 1993): prospect (the extent to which the environment offers an overview over a scene), concealment (environmental affordance of hiding places for potential offenders), and entrapment (the extent to which the environment offers possibilities to escape in case of an emergency).

In Chapter 2, we have presented a set of studies that confirm the previously recognized role of safety-related environmental characteristics in the environmental safety appraisal process (e.g., Fisher & Nasar, 1992; Loewen et al., 1993; Blöbaum & Hunecke, 2005; Haans & de Kort, 2012). Judgments about the extent to which the environment depicted by the photographs in our stimulus set offered prospect, concealment, and entrapment were found to account to a large extent (~75%) for variation in appraisals of environmental safety. As we were primarily interested in validating the role of the safety-related environmental characteristics in the environmental safety appraisal process, we collapsed across individual participants' responses and simply considered the average responses on the level of our stimuli. Yet, such an approach inevitably omits potential differences in the safety appraisal process on an individual level – differences that may, for example, be expressed in a general individual tendency to experience feelings of safety (i.e., a distal influence on perceptual judgments in the proximate environment). Therefore, in the current chapter, we aim to extend the basic findings from Chapter 2 by examining both the distinct contributions of individual-level and environmental-level characteristics to the safety appraisal process, as well as potential person-environment interactions.

Individual susceptibility to safety-related environmental information

The theoretical keystones of the proximate cue framework do not explicitly consider the role that individual characteristics play in the formation of safety perceptions from appraisals of environmental characteristics. Still, surveying the available literature, one may discern a strong focus on detailing individual differences in safety perceptions on a biological level. For example, many of the studies investigating the impact of environmental characteristics on environmental safety perceptions also consistently report higher levels of fear or lower appraisals of safety for women as compared to men (e.g., Fisher & May, 2009; Boomsma & Steg, 2014; Blöbaum & Hunecke, 2005; Fisher & Nasar, 1992; Nasar et al., 1993; Loewen et al., 1993). Yet, investigating differences between the sexes on the biological level without trying to account for the mechanisms that motivate these differences may divert us from gaining a more sophisticated understanding of the psychological variables underlying individual differences in the perception of environmental safety.

A number of psychological characteristics may more accurately reflect the mechanism through which these differences come into existence. For instance, a number of studies have pointed to the finding that women are more prone to feelings of vulnerability (e.g., Riger & Gordon, 1981; Hale, 1996), which, given that people who feel more vulnerable tend to develop a greater fear of crime and more feelings of insecurity (e.g., Haans & de Kort, 2012; Cossman & Rader, 2011; Van der Wurff, Van Staalduinen & Stringer, 1989), may already provide a more informative explanation for differences found between the sexes. Apart from biological sex, a small number of authors also looked into the effect of more psychological variables, such as trait anxiety (Blöbaum & Hunecke, 2005) or psychological gender (Haans & de Kort, 2012; Blöbaum & Hunecke, 2005) on safety perceptions.

These studies tend to give an account of safety perceptions on a general level of individual differences; some people exhibit a certain characteristic (e.g., they are endowed with the female sex, or identify with a masculine gender type) that directly influences their perception of safety. However, people's perception of their environment is neither unilaterally shaped by their idiosyncratic tendencies nor by a fixed amount of environmental information available to them, but rather dependent on the dynamic interplay between people and their environment. For example, some people may perceive the environment as more unsafe when the environment offers low levels of prospect, while others' safety perception may not be affected at all by the level of prospect in an environment. Blöbaum and Hunecke (2005) provide evidence for the existence of such a dynamic interaction between individual differences and the interpretation of safety-relevant environmental information, showing that the impact of entrapment, as assessed by expert judges on-site, was indeed different for men than for women. Elevated levels of entrapment were associated with larger increases in reported perceptions of danger for women than for men – a finding which was recently replicated (Boomsma & Steg, 2014). Yet, the proposition that the weighing of safety-relevant environmental information depends on individual characteristics has not received the appropriate attention it deserves. Consequently, we are interested in investigating a dynamic interaction; do individual differences also lead to differences in how safety-related environmental characteristics are weighed in the perception process?

Given the dearth of guiding theoretical and empirical work on individual differences in safety perceptions, our goal is to explore which personal characteristics may be suitable candidates for accounting for potential differences in the weighing of environmental information. A first rather obvious concept that one may think of in relation to perceptions of safety is anxiety. While anxiety often refers to a more transitory emotional state characterized by heightened tension and apprehension, which may be triggered by both physical and psychological (e.g., worry about potentially stressful situations) stimuli, Spielberger (e.g., Spielberger, 1972; Spielberger & Rickman, 1990) distinguished this transitory and temporally demarcated anxiety state (state anxiety) from a more stable individual propensity to experience these anxiety states (trait anxiety). According to Spielberger, "persons who are high in trait anxiety tend to perceive a larger number of situations as dangerous or threatening than persons who are low in trait anxiety, and to respond to threatening situations with state anxiety elevations of greater intensity" (Spielberger, 1972, p. 39). This conceptualization of trait anxiety as a tendency to perceive more situations as dangerous is again formulated on a more general level of explanation, and does not explicate the interaction that may exist between person and environment. One possibility may well be that persons high in trait anxiety are more sensitive to negative safety-related environmental characteristics of the environment, and subsequently judge these environments as being more dangerous than persons low in trait anxiety, who are less sensitive to this information.

This line of reasoning is consistent with findings from literature on clinical anxiety highlighting selective attention to threat or danger stimuli by patients with anxiety disorders (e.g., Beck, 1976; Beck, Emery, & Greenberg, 1986; Mogg, Bradley, Williams, & Mathews, 1993). For example, Beck's schema model proposes that there exist mood-congruent biases in clinical anxiety that operate on all levels of cognitive processing, such that anxious individuals are more prone to selectively process anxiety-relevant information (Beck, 1976; Beck et al., 1986). Indeed, empirical work has evidenced this bias toward anxiety-related information in early stages of information processing (e.g., Mogg et al., 1993; Mathews, 1990). Thus, there is indeed an indication that anxiety leads to an altered mode of orientation with regard to the processing of relevant information from the environment. Nonetheless, since these experiments involved patients diagnosed with clinical anxiety, we should be cautious with assuming these findings will generalize to the broader non-clinical population.

Research aims

In the current chapter we aim to replicate the basic findings from Chapter 2 with regard to the role of the safety-related environmental characteristics (i.e., prospect, concealment, and entrapment), and gain a deeper understanding of the psychological processes underlying an individual's processing of these site-specific safety-related characteristics of the environment when making an appraisal of the safety of an environment. In Study 3.1, we test the hypothesis that there are individual differences in relative susceptibility to safety-related environmental characteristics (i.e., prospect, concealment, and entrapment) when making safety appraisals of environments. In Study 3.2, we explore whether these individual differences may be accounted for by individual variation in safety-relevant personality characteristics. A secondary aim of these two studies is not only to provide further support for previous observations of differences in safety appraisals between the two sexes, but also to extend these findings by exploring whether this effect of biological sex can be explained by individual variation in safety-relevant individual characteristics.

Study 3.1

In the first study, we collected participants' appraisals of environmental safety for a large set of photographs of nocturnal urban environments that were evaluated on prospect, concealment, and entrapment in a preceding calibration study. We expected that prospect would be positively associated with environmental safety perception, and that concealment and entrapment would be negatively associated with environmental safety perception. More importantly, however, we expected to find substantial individual differences in the relative susceptibility to these safety-related environmental characteristics when making an appraisal of the safety of an environment. Additionally, we expected to find that men, as compared to women, would report higher judgments of environmental safety.

Method

Participants and design. We employed a within-subjects design in which the participants judged photographs of nocturnal environments. The dependent variable was participants' appraisal of the environmental safety of the presented photographs. 83 first-year students (22 females and 61 males, M_{age} = 19.58, SD_{age} = 2.13, age range = 17 - 33 years) of the Eindhoven University of Technology participated in the study for partial fulfilment of requirements for an introductory methodology course. Because the student body for this course also included international students, we constructed both a Dutch (N = 78) and an English (N = 5) version of the experiment. The results of our analyses were not affected by either including or excluding the smaller subsample who performed the study in English. Therefore, in the remainder of this chapter we treat both groups as one.

Materials and measures. We used the same stimulus set that was used in the first two studies presented in Chapter 2, comprising 100 high resolution photographs of nocturnal urban environments (see page 35 for examples of the stimuli used). None of the participants lived in the two villages where the photographs were taken (i.e., Best and Geldrop). The environments in the photographs were selected to reflect a wide range of settings that people in urban areas may encounter on a daily basis, but were devoid of humans and animals to explicitly exclude influences that may be attributed to the visual presence of others in these environments.

Calibration. To determine the average prospect, concealment, and entrapment judgments for each photograph in our stimulus set, a calibration study preceded the main experiment. In this calibration study, 65 judges rated the photos. One group rated the photos within our stimulus set on prospect (N = 24), a second group rated the photos on concealment (N = 20), and a third group rated the photos on entrapment (N = 21). Descriptives for our measures of the safety-related characteristics are presented in *Table 3.1*.

	M	SD	Min	Max
Prospect	3.00	.97	1.35	4.51
Concealment	2.83	.65	1.88	4.30
Entrapment	3.19	.83	1.86	4.79

Table 3.1. Descriptives for the measures of prospect, concealment, and entrapment in the calibration study.

	Prospect	Concealment	Entrapment
Prospect	-		
Concealment	-.85***	-	
Entrapment	-.80***	-.79***	-

*Note. *** p < .001*

Table 3.2. Correlations between the measures of prospect, concealment, and entrapment in the calibration study.

We measured the safety-related environmental characteristics using the same five-point response category format items we used in Study 2.1. For a complete overview of the items used, see Appendix B. Even though the safety-related characteristics were evaluated by different groups of participants, the measures of prospect, concealment, and entrapment were highly correlated (see *Table 3.2*).

Interrater agreement on the appraisals of the safety-related environmental characteristics, as measured by the average deviation[1] (e.g., Burke, Finkelstein, & Dusig, 1999) and the intraclass correlation coefficient[2] (ICC; e.g., Shrout & Fleiss, 1979; LeBreton & Senter, 2008) showed considerable agreement among judges when rating prospect and entrapment (see *Table 3.3*). Even though there was notably less agreement between judges on appraisals of concealment, the ICC score of .24 still indicates a moderately large effect size. Furthermore, the average reliabilities (Cronbach's α) of the aggregate scores of prospect, concealment, and entrapment were excellent (all αs higher than .86, see *Table 3.3*). Lastly, the average measures of the safety-related characteristics in the current study correlated highly with the average measures of Study 2.1 (see right-hand column of *Table 3.3*).[3] These findings from the calibration study suggest that there was sufficient scale reliability and overlap between people on their appraisal of safety-related characteristics of the environment to warrant using aggregate scores for each photograph as independent variables in our main study.

	Average deviation	Intraclass correlation coefficient	Cronbach's Alpha	Correlation with Study 2.1
Prospect	0.68	.48	.96	.90**
Concealment	1.01	.24	.86	.81**
Entrapment	0.84	.41	.94	.88**

*Note. ** p < .001*

Table 3.3. Interrater agreement indices for the measures of prospect, concealment, and entrapment in the calibration study.

Main study. Since participation in the main study was scheduled in the hours allotted for an introductory research methods course during one week, there was a 30 minute time restriction on the total time participants would be able to participate. Based on the average response time in the calibration study, we selected a subsample of 43 stimuli from our stimulus set.

1 The average deviation (AD) is calculated as follows: for every photo in the stimulus set we calculated the deviation of the rating by a judge from the average rating. These deviations were summed and divided by the number of judges. We then summed for every judge the deviation of a judgment from the average judgment and divided this sum by the total number of judgments made by a judge (Burke, Finkelstein, & Dusig, 1999). The resulting average deviation is reported in *Table 3.3*. For five-point scales, scores lower than 0.8 may be interpreted as indicating high agreement (LeBreton & Senter, 2008).

2 The intraclass correlation coefficient describes the average correlation between ratings by different judges (Shrout & Fleiss, 1979). The ICC should be interpreted as a measure of effect size (LeBreton & Senter, 2008).

3 While both the participants from Study 2.1 and the calibration study were sampled from the J. F. Schouten participant database, there was no overlap in participants between the two samples.

We used the same five-point response category format measure of perceived environmental safety we used in Chapter 2 (see Appendix B). We calculated the mean score across these items and used this composite measure in our analyses (α = .91).

Procedure. The participant was welcomed by the experiment leader, directed to one of eight available cubicles, and instructed to complete an informed consent form. 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 approximately 50 cm in front of a color calibrated 19" LCD monitor screen running at a 1600 pixels by 1200 pixels resolution and 60 Hz refresh rate, and viewed a total of 43 randomly presented photographs of nocturnal urban environments. The participant was instructed to imagine traveling alone at night through these environments. Each photograph was presented for five seconds after which the participant answered three questions measuring their appraisal of environmental safety. This yielded a total of 3550 ratings of environmental safety. While the participant answered the questions, a smaller version of the presented photograph was still present on the screen. After completing the questions for all photographs, the participant responded to three demographic questions about biological sex (coded as female = 0, male = 1), age, and current residence.

Results and discussion

Variance in environmental safety perceptions may be attributed either to characteristics of the environment or to systematic differences between persons. We employed a multi-level model, also called hierarchical model or random coefficient model (Snijders & Bosker, 1999), to take into account the nested structure of our data (repeated observations of perceptions of stimuli nested within individuals). Multi-level models partition the total variance into components. In our models, one component measures the variance at the level of the stimulus (i.e., the environment), and the other component measures the variance at the level of the individual, thus allowing estimation of random variance at both our levels of interest (e.g., Levine, 1996). Our results showed that a substantial amount of the variance, approximately 30%, could be attributed to the person (see empty model, *Table 3.4*). However, the bulk of the variance in safety perceptions (70%) could be attributed to characteristics of the environments depicted in our stimuli.

Given that the large number of observations increases the probability of finding very small and inconsequential effects, we tested our models against a .01 alpha level. The first step in our analysis was to test a model that predicted appraisals of environmental safety from environmental characteristics. In this first model (Model A, see *Table 3.4*), we included the prospect, concealment, and entrapment scores obtained in the calibration study as independent variables predicting participants' appraisals of environmental safety.

As expected, both prospect (β = .109, z = 5.07, p < .001) and, to an even larger extent, entrapment (β = -.427, z = -19.17, p < .001) were significant predictors of environmental safety appraisal. Thus, in accordance with previous findings, an increase in the appraisal of prospect in an environment is associated with an increase in perceived environmental safety, while an increase in the perceived level of entrapment is associated with a decrease in perceived environmental safety. We did not find a similar association between appraisals of concealment and environmental safety (β = -.002, z = -.12, p = .907).

	Empty model	Model A	Model B
Prospect		.109**	.109**
		(.021)	(.021)
Concealment		-.002	-.002
		(.018)	(.018)
Entrapment		-.427**	-.427**
		(.022)	(.022)
Biological sex			.264**
			(.055)
Constant	-.084	-.084	-.151
	(.056)	(.056)	(.052)
Var(constant)	.249	.257	.120
	(.041)	(.041)	(.032)
Var(residual)	.584	.281	.281
	(.013)	(.007)	(.007)
Log likelihood	-4007.22	-3021.80	-3011.58
N observations		3550	
N participants		83	

*Note. ** p < .001*
Model A: environmental-level predictors only
Model B: Model A + biological sex

Table 3.4. Maximum likelihood estimates for Study 3.1 (standard error between brackets; standardized coefficients).

Next, we examined individual differences in the weighing of environmental information. Both the effect of prospect and entrapment varied substantially between participants (Model A, *Table 3.4*). For example, while the average standardized slope of entrapment was -.427, the standard deviation of this slope was .143. This implies that 95% of the slopes fell between -.713 and -.141. Thus, in the case of entrapment, some participants were not very sensitive to the amount of entrapment, while other were more so predisposed. Likewise, while the average slope of prospect was .109, the standard deviation of the slope was .100, implying that 95% of the slopes fell between -.091and .395, demonstrating that the participants in our study were differentially sensitive to prospect as well. These results show that people exhibit large variability in their sensitivities to safety-related characteristics of the environment when making appraisals of the safety of an environment.

The last part of our analysis focused on explaining part of the variance residing at the person level by looking at biological sex. We extended Model A by including biological sex as predictor of environmental safety appraisal (see *Table 3.4,* Model B). We found that biological sex indeed significantly affected environmental safety appraisals (β = .264, z = 4.81, p < .001), such that men, as compared to women, were more predisposed to appraise a certain environment as a safe environment.

In sum, our results replicate the results from Chapter 2 and are in line with previous findings from the literature (e.g., Fisher & Nasar, Blöbaum & Hunecke, 2005), showing that safety-related environmental characteristics account for a large share of the variance in environmental safety appraisals. The level of entrapment an environment offers was found to be an important predictor of people's appraisal of environmental safety. Although the effect is decidedly smaller, our results also support previous findings showing that appraisals of prospect are positively associated with environmental safety perceptions (e.g., Fisher & Nasar, 1992; Loewen et al., 1993; see also Chapter 2). More importantly, our results extend our previous studies that focused mainly on the validity of environmental cues in the environmental safety appraisal process, showing that there are marked individual differences in the importance attributed to the safety-related environmental characteristics in achieving these appraisals. Finally, our results are also in line with previous findings showing an effect of biological sex on environmental safety perceptions (e.g., Fisher & May, 2009; Boomsma & Steg, 2014; Blöbaum & Hunecke, 2005; Fisher & Nasar, 1992).

Two issues may be raised with respect to the findings from Study 3.1. First, while the results show that there is indeed large individual variability in weighing safety-related environmental information, we do not yet attempt to explain why these differences may occur. Second, while we also replicate previous findings, showing that men, as compared to women, are more inclined to appraise a certain environment as safe, we have argued that it may be more interesting to look at potential psychological differences between the sexes that may mediate this effect of biological sex on safety appraisals. We attempted to deal with these issues in a follow-up study.

Study 3.2

In Study 3.2 we again collected participants' appraisals of environmental safety for the environments in our stimulus set. We expected that prospect would be positively associated with environmental safety appraisals, and that concealment and entrapment would be

negatively associated with environmental safety appraisal. Furthermore, we expected that participants would again demonstrate substantial individual variation in their susceptibility to these safety-related environmental characteristics.

The main aim of Study 3.2 was to explain individual variation by introducing the personality characteristics trait anxiety, perceived attractiveness, and perceived power into our model. On the level of the individual, we expected that both trait anxiety and perceived attractiveness would be negatively associated with the measurements of perceived environmental safety. We further expected that perceived power would be positively associated with perceived environmental safety. Following our discussion highlighting selective processing of anxiety-relevant information in clinically anxious populations (e.g., Beck, 1976; Mogg et al., 1993), we expected that trait anxiety would be associated with individual differences in the susceptibility to safety-related environmental characteristics. More specifically, we expected a positive interaction between trait anxiety and prospect, a negative interaction between trait anxiety and concealment, and a negative interaction between trait anxiety and entrapment.

A secondary aim of the study was to replicate the effect of biological sex found in Study 3.1, and test whether we could account for this effect with the safety-related personality variables that we entered into the model. We expected to find that biological sex affects environmental safety appraisal such that men, in general, report higher levels of environmental safety as compared to women. We also expected that trait anxiety, perceived attractiveness, and perceived power would, at least partially, mediate this relationship between biological sex and environmental safety appraisal.

Method

Participants and design. The design of Study 3.2 was the same as Study 3.1. In addition to the variables used in Study 3.1, we also included measures of trait anxiety, perceived attractiveness and perceived power as predictor variables at the individual level. A total number of 216 participants (122 males and 93 females; M_{age} = 23.45, SD_{age} = 10.25, age range = 18 - 66 years) participated in the present study. Due to a malfunction in the experiment software we failed to record demographics for one participant. In this group of 216 participants, 105 first-year students (39 females and 65 males; M_{age} = 19.76, SD_{age} = 2.72, age range = 18 - 37 years) participated to partially fulfill course requirements for an introductory research methods course (this study was performed one year after Study 3.1; no students participated both in Study 3.1 and the present study). The remaining 111 participants (57 males and 54 females; M_{age} = 26.90, SD_{age} = 13.14, age range = 18 - 66 years) were registered in Eindhoven University of Technology's J.F. Schouten participant database and responded to an invitation to participate in our study. These participants received €5,- as compensation for their participation.

Materials and measures. The same 43 photos of nocturnal urban environments we used in Study 3.1 were used in the present study. We again measured perceived environmental safety using three items (see Appendix B), calculated the mean score across the three items and used this composite score as dependent variable in our analysis (α = .95).

Personality characteristics. We measured trait anxiety[4] using a translated version of the State-Trait Anxiety Inventory (STAI; adapted from Blöbaum and Hunecke, 2005). Participants indicated for 20 items (e.g., "*I often worry about things that do not really matter*"; see Appendix B) to what extent the printed statement reflected their own personality on a response category format ranging from (1) "almost never" to (4) "almost always". Items 6, 11, and 14 were removed after a factor analysis of the 20 STAI items revealed these items to have factor loadings smaller than .5. We then calculated the average score across all remaining items for each participant and used this aggregate score in our analyses (α = .93). Sample descriptives for our measures of individual characteristics are presented in *Table 3.5*.

	Overall		Females		Males	
	M	SD	M	SD	M	SD
Trait anxiety	1.91	.54	2.06	.53	1.80	.52
Attractiveness	3.30	.93	2.98	.70	2.27	.65
Power	2.58	.76	2.75	.92	3.71	.69

Table 3.5. Descriptives for the measures of trait anxiety, perceived attractiveness, and perceived power in Study 3.2

	Trait anxiety	Attractiveness	Power
Trait anxiety	-		
Attractiveness	.15**	-	
Power	-.18**	-.41**	-

Note. ** p < .001

Table 3.6. Correlations between the measures of trait anxiety, perceived attractiveness, and perceived power in Study 3.2.

4 We also measured neuroticism, a personality characteristic that is closely related to trait anxiety, using the Dutch version of the Neuroticism scale from the Big Five Inventory (Denissen, Geenen, van Aken, Gosling, & Potter, 2008). In line with previous findings (e.g., Barlow, 1988), we found that the two constructs were highly correlated (r = .79, p < .001). In fact, a principal axis factor analysis with oblique rotation revealed that we could not disentangle the two constructs in such a way as to be able to regard them as distinct concepts. Since trait anxiety was our main variable of interest, we report here only the results for trait anxiety.

We measured the extent to which participants feel that they or their possessions are attractive targets for criminals using a perceived attractiveness scale (adapted from Haans & de Kort, 2012). Participants responded to three five-point response category format items (e.g., *"To what extent do you regard yourself to be an attractive or unattractive target for potential criminals"*; see Appendix B) ranging, for example, from (1) "very attractive", through (3) "neither attractive nor unattractive" to (5) "very unattractive". We calculated the average score across the three items for each participant and used this aggregate score in our analyses (α = .70). Sample statistics are presented in *Table 3.5*.

We measured the extent to which people feel like they will be able to deal with situations in which they are victims of physical criminal behavior with a perceived power scale (Haans & de Kort, 2012). Participants responded to three five-point response category format items (e.g., "*To what extent do you regard yourself incapable or capable of escaping from an attacker?*"; see Appendix B), ranging from (1) "very incapable", through (3) "neither incapable nor capable", to (5) "very capable". We calculated the average score across the three items for each participant and used this aggregate score in our analyses (α = .81). Sample statistics and correlations between the measures of individual characteristics are presented in *Table 3.5* and *Table 3.6*.

Procedure. The procedure and conditions of the present study were analogous to those of Study 3.1, except that the participants now completed three questionnaires measuring trait anxiety, perceived attractiveness, and perceived power before viewing the stimuli.

Results and discussion

We again employed a multi-level model for our statistical analysis (See *Table 3.8* for the results, p. 70). Before proceeding to the main analysis we tested an empty model without explanatory variables to see how the variance was distributed across the two levels (i.e., persons and stimuli) in our sample. Approximately 35% of the variance resided on the level of the person, which was close to the 30% estimate we found in Study 3.1. Thus, we replicate Study 3.1's finding that although the better part of the variance in environmental safety perceptions resides at the level of the stimulus, a substantial amount of variance also resides at the level of the person.

Safety-related environmental characteristics. Similar to the analysis in Study 3.1, the first step in our analysis was to test a model predicting appraisals of environmental safety from the safety-related characteristics (Model A, see *Table 3.8*). We found a large, negative effect of entrapment on environmental safety appraisals, with a comparable effect size to the effect size found in Study 3.1 (β = -.460, z = -26.01, p < .001). Similar to Study 3.1, we found a significant, but smaller, effect of prospect on perceived environmental safety

(β = .068, z = 3.72, p < .001), and no effect of concealment (β = -.025, z = -2.00, p = .045).

Individual differences. In the next step of our analysis we focused on the role of individual differences in explaining variation in environmental safety perceptions. First, we included biological sex as a predictor variable in Model B (see *Table 3.8*). As expected, we replicated Study 3.1's finding that men, as compared to women, were more inclined to appraise a particular environment as safe (β =.205, z = 5.28, p < .001).

In Model C, we included both trait anxiety, perceived attractiveness and perceived power as predictors of environmental safety appraisal at the level of the person (see *Table 3.8*). We found a moderate negative effect of trait anxiety on perceived safety (β = -.163, z = -4.26, p < .001). An increase in the trait anxiety score (i.e., participants that are more prone to experience anxiousness) was associated with lower evaluations of the safety of our environments. Against our expectations, we did not find the anticipated effects of perceived attractiveness and perceived power on perceived environmental safety (both zs ≤ |2.35| and both ps ≥ .176).

After inclusion of the personality characteristics in our model the effect of biological sex was no longer significant, which suggested that there is an indirect effect of biological sex on safety perceptions through (one of) these personality characteristics (see *Figure 3.1*). In our statistical model, we test the significance of any indirect effect *ab* by dividing the estimation of the indirect effect *ab* by its standard error σ_{ab} and comparing this value (z') to the associated sampling distribution (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002). The results of the mediation analysis showed a significant indirect effect of trait anxiety (z' = 4.10, p <. 001), while the indirect effects of perceived attractiveness and perceived power were not significant (both z's < 2.4; see *Table 3.7*). Interestingly, while the effects of biological sex on perceived attractiveness (β = -.298, z = -31.88, p < .001) and perceived power (β = .379, z = 40.35, p < .001) were larger than the effect of biological sex on trait anxiety (β = -.127, z = -14.69, p < .001), only trait anxiety mediated the effect of biological sex on environmental safety appraisal.

The interaction between person and environment. In the final step of our analyses we tested how personality characteristics at the level of the person interact with the safety-related environmental characteristics at the level of the stimulus. Model D (see *Table 3.8*) extended the previous models by including all possible interactions between the three safety-related environmental characteristics (i.e., prospect, concealment, and entrapment) and the three personality characteristics (i.e., trait anxiety, perceived attractiveness, and perceived power).

As expected, we found a small but significant interaction between trait anxiety and prospect (β = .050, z = 2.78, p = .005), such that higher levels of trait anxiety paired with higher levels of prospect lead to higher appraisals of environmental safety. This suggests that,

when making a safety appraisal of the environment, people who are high in trait anxiety are more sensitive to having a good overview over the environment when compared to people low in trait anxiety. Furthermore, we found a small significant interaction between perceived power and entrapment (β = .059, z = 3.13, p = .002), such that higher levels of perceived power in combination with higher levels of entrapment are associated with higher ratings of perceived environmental safety. This suggests that people with a high level of perceived power (i.e., people who feel they are able to deal with potential offenders) are less susceptible than people with lower levels of perceived power to the degree of entrapment in the environment when making a safety appraisal of that environment. We did not find any other significant interactions between the three personality characteristics and the safety-related environmental characteristics (all zs ≤ |.240|, all ps ≥ .016).

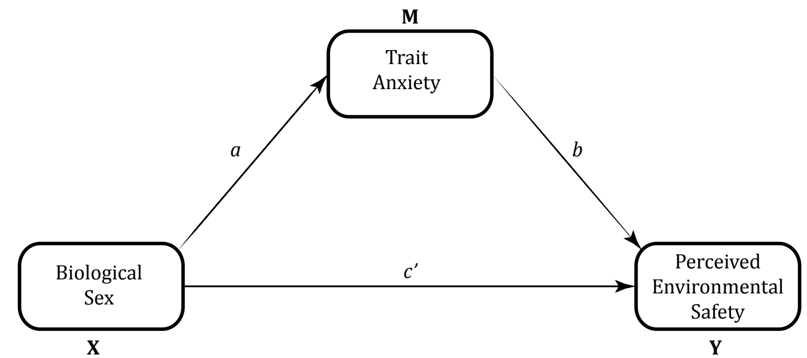

Figure 3.1. A mediation model with a direct effect (c') of biological sex (X) on perceived environmental safety (Y) and an indirect effect through trait anxiety (M; a*b).

	a	SDa	b	SDb	z'
Trait anxiety	-.127**	.009	-.163**	.038	4.10**
Attractiveness	.298**	.009	-.100	.043	2.32
Power	-.379**	.009	.060	.044	1.36

*Note. ** p < .001*

Table 3.7. Results of the mediation analysis in Study 3.2.

General discussion

In the current chapter we have broadened the scope of our investigation of the safety appraisal process; not only did we examine the validity of safety-related environmental cues (see also Chapter 2), but we also investigated potential individual differences in the weighing

	Empty model	Model A	Model B	Model C	Model D
Prospect		.068**	.068**	.068**	.068**
		(.018)	(.018)	(.018)	(.018)
Concealment		-.025	-.025	-.025	-.025
		(.012)	(.012)	(.012)	(.012)
Entrapment		-.460**	-.460**	-.460**	-.460**
		(.018)	(.018)	(.018)	(.017)
Biological sex			.205**	.091	.091
			(.039)	(.046)	(.046)
Trait anxiety				-.163**	-.163**
				(.038)	(.038)
Attractiveness				-.100	-.101
				(.043)	(.043)
Power				.060	.060
				(.044)	(.044)
Prospect x Trait anxiety					.050*
					(.018)
Concealment x Trait anxiety					-.015
					(.013)
Entrapment x Trait anxiety					.042
					(.017)
Prospect x Attractiveness					-.036
					(.019)
Concealment x Attractiveness					-.032
					(.014)
Entrapment x Attractiveness					-.004
					(.019)
Prospect x Power					.046
					(.020)
Concealment x Power					.025
					(.014)
Entrapment x Power					.059*
					(.019)
Constant	.034	.034	.053	.042	.042
	(.042)	(.042)	(.040)	(.037)	(.037)
Var(constant)	.363	.371	.328	.287	.287
	(.037)	(.037)	(.032)	(.028)	(.028)
Var(residual)	.696	.348	.348	.348	.347
	(.010)	(.005)	(.005)	(.005)	(.005)
Log likelihood	-11738.94	-8935.16	-8922.03	-8922.03	-8884.57
N observations			9211		
N participants			215		

*Note. ** p < .001, * p < .01*
Model A: environmental-level predictors only
Model B: Model A + biological sex
Model C: Model B + trait anxiety, perceived attractiveness, and perceived power
Model D: Model C + cross-level interactions

Table 3.8. Maximum likelihood estimates for Study 3.2 (standard error between brackets; standardized coefficients).

of these safety-related information cues as well as the role of individual characteristics in the safety appraisal process. Both studies presented in the current chapter indicated that approximately 30% of the variance in environmental safety perceptions could be attributed to individual characteristics. However, in both studies the bulk of the variance could be attributed to characteristics of the environments depicted in our stimuli. These results are in line with previous research showing comparable ratios between individual and environmental sources of variance in environmental preference (e.g., Stamps, 1996).

Safety-related characteristics of the environment

We replicated previous findings from the literature (e.g., Fisher & Nasar, 1992; Blöbaum & Hunecke, 2005; see also Chapter 2), highlighting the importance of appraisals of safety-related environmental characteristics when making an appraisal of the safety of an environment. Moreover, we replicate the results from Chapter 2, showing that these findings not only apply to the small subset of specific environments typically employed in this type of research, but also to a wider variety of urban environments that reflect a more representative sampling of environments that people find themselves in on a daily basis.

Similar to the findings from Study 2.1, the extent to which people judge an environment to possess characteristics that impede escape from dangerous situations (i.e., entrapment) was found to have a large influence on people's safety perceptions. In both studies, higher levels of entrapment were associated with lower judgments of perceived environmental safety. Similarly, across our two studies we found the extent to which an environment offers a good overview to an observer (i.e., good prospect) to be positively associated with judgments of environmental safety. The extent to which the environment offers opportunities for potential criminals to hide (i.e., concealment) did not affect these safety appraisals (see also Chapter 2). Thus, with respect to the effect of environmental characteristics on environmental safety perceptions, we replicate the findings from the literature showing that of the three safety-related environmental characteristics under investigation, appraisals of entrapment have the largest influence on safety perceptions (Blöbaum & Hunecke, 2005).

More importantly, the main aim of the presented studies was investigating individual differences in the weighing of these safety-related environmental characteristics in the safety appraisal process. Both Study 3.1 and Study 3.2 provide evidence for substantial variability between people in their susceptibility to environmental information. For example, while some people show a substantial decrease in environmental safety appraisal when presented with environments offering a high level of entrapment, others' appraisals are only minimally affected by the level of entrapment. Thus, while the proximate cue framework may allow us to identify the general role these environmental characteristics play in the safety appraisal process, the omission of individual variation hampers a more thorough understanding of how environmental safety perceptions are formed. Accordingly, we should aim to accommodate the proximate cue framework to allow for individual variation and investigate the mechanisms underlying this variation.

Safety-related individual characteristics

Our results confirm that perceptions of the safety of an environment not only depend on characteristics of the environment, but also on the personal characteristics of an observer. Both studies presented in the current chapter demonstrate that a substantial amount of variability in safety appraisals can be attributed to the person. The investigation of individual differences in safety perceptions has often focused on biological sex (e.g., Blöbaum & Hunecke, 2005; Fisher & Nasar, 1992; Boomsma & Steg, 2014). Across the wide range of environments in our two studies, we replicate such an effect of biological sex on environmental safety appraisals, showing that men have more favorable perceptions of the safety of these environments than women. Apart from this biological explanation, we also distinguished a number of safety-related psychological characteristics that we expected to affect perceptions of environmental safety: trait anxiety, perceived attractiveness of being selected as a target by criminals, and perceived power. As expected, we found that the propensity of people to experience anxiousness (i.e., trait anxiety) strongly impacts their appraisal of the safety of an environment. People who are more prone to experience anxiousness perceive environments to be more unsafe as compared to people who are less prone to experience anxiousness. In contrast, the extent to which one perceives oneself an attractive target for potential offenders (i.e., perceived attractiveness) and the extent to which one perceives oneself to be able to deal with potentially dangerous situations (i.e., perceived power) were not found to directly impact the appraisal of safety of the environment. Yet, we included perceived attractiveness and perceived power in our model because these individual-level variables were previously shown to affect environmental safety appraisals (e.g., Haans & de Kort, 2012). One potential explanation for this finding is that the previously found effects of perceived attractiveness and perceived power may have been driven by differences in trait anxiety. While our results may thus suggest that trait anxiety is more important, understanding the interrelationships between these variables was not the main goal of the current set of studies and future research will need to replicate these results and examine these relationships in more depth before any stark conclusion may be derived.

In Study 3.2, the effect of biological sex was no longer significant after adding the personality characteristics to our model, which suggested that the effect of biological sex on environmental safety appraisal may be qualified by an indirect effect of these personality characteristics. Indeed, the mediation analysis performed in Study 3.2 revealed trait anxiety as a significant mediator of the relationship between biological sex and environmental safety appraisal. Thus, a large part of the finding that men tend to feel more safe in general may be explained by the lower levels of trait anxiety found in men. These findings demonstrate how we may successfully employ psychological characteristics to explain individual differences that appear to exist on a biological level.

Interactions between the environment and the individual

In Study 3.2, we examined the interaction between personality characteristics and environmental perception. Based on Beck's schema model and related empirical findings pertaining to clinical anxiety (e.g., Beck, 1976; Mogg et al., 1993), we hypothesized that people who have a high propensity to experience anxiety are more prone to selectively process safety-relevant information and thus more susceptible to safety-related environmental characteristics. We did not identify interactions between trait anxiety and concealment or entrapment, but we did find a fairly small interaction showing that people who exhibit higher levels of trait anxiety give more weight to environmental information related to having a good overview over the situation (i.e., prospect), as compared to people who exhibit lower levels of trait anxiety.

Without having prior expectations, we also explored the interactions between environmental characteristics, and perceived power and perceived attractiveness. We found a significant interaction between perceived power and entrapment; when judging the safety of an environment, people who perceived themselves capable of dealing with potentially dangerous situations were less affected by environmental characteristics that impede escape opportunities than people who perceived themselves to be less capable of dealing with dangerous situations. Given that the interactions with prospect and concealment were not significant, the interaction between perceived power and entrapment suggests that people who are less able to fend for themselves are more attentive to environmental characteristics which may further reduce their behavioral options in case of danger.

Importantly, although the effects are not very large, these findings provide evidence for the existence of interactions between psychological characteristics on the individual level and appraisals of environmental characteristics. Moreover, building on findings demonstrated in a population of clinically anxious people (e.g., Mogg et al., 1993), they provide one of the first systematic demonstrations of a theory-driven hypothesized interaction between the individual and the environment in the safety appraisal process.

Limitations

A number of limitations may be raised with respect to the two studies presented in the current chapter. First, in our analyses we treated the average ratings of the safety-related environmental characteristics (i.e., prospect, concealment, and entrapment) obtained from the calibration study as fixed indicators for each stimulus. However, the results of the reliability analyses in our calibration study were mixed. Given the subjective nature of these environmental appraisals, the reliability metrics for the responses to the prospect and entrapment measures were acceptable (i.e. average deviation, intraclass coefficient and Cronbach's α). The intraclass coefficient and average deviation for the responses on the concealment measure were only moderately acceptable. This suggests that people tend to agree when they have to evaluate the overview they have over an environment or the level of entrapment in an environment, but agree to a much lesser extent when they have to evaluate whether there are characteristics of the environment that afford potential offenders a hiding place. One potential explanation for this larger variation is that the use of 2D images depicting real-world scenes on a monitor screen may not be ideal for forming an accurate impression of the degree of concealment an environment offers. It would therefore be interesting to examine whether assessing the degree of concealment in real-world settings would yield higher agreement between judges.

More importantly, while we focus mainly on identifying and explaining individual differences in the perception of environmental safety, there already seem to exist some individual differences in perceptual judgments of the informational cues identified in the proximate cue framework. This may be due to the measurement items used in the current studies, or perhaps to underlying variables, yet to be explored and examined, affecting this environmental appraisal. A potential consequence of fixing this individual variability is that we may overlook how (subtle) individual differences in the appraisal of safety-related environmental characteristics affect environmental safety appraisals, or how individual characteristics such as trait anxiety influence how individuals perceive these environmental characteristics. Future research could focus on investigating these interesting questions.

Second, the studies were performed in a safe and controlled laboratory setting and participants were asked to imagine walking through the depicted environments. We did not measure the level of anxiousness or fear participants experienced at the time of participation, but we assume that most people were generally at ease. The actual experience of fear or anxiousness when walking outside at night may intensify or alter the process of environmental perception in ways that we do not yet fully understand.

Third, although we aimed to enhance the generalizability of our stimuli by using a large sample of representative environments, the selection of environments reflect the researchers' on-site decision about which environments to include. As such, the selection does not represent a true random sample of all possible night-time environments. Future research may address this issue by creating stimulus sets from environments selected through truly random selection methods.

Finally, the currently presented conclusions apply primarily to urban, night-time environments. We cannot yet be confident that these findings will also apply to drastically different types of environments, such as rural or natural environments, or even to the same urban environments by day. Future research may be aimed at contrasting these different types of environments with the nocturnal urban environments used in the present studies.

Conclusion

The two studies presented in the current chapter provide evidence that substantial differences exist between people in their susceptibility to safety-related characteristics of the environment when making an appraisal of the safety of an environment. We replicate previous findings relating prospect, concealment, and entrapment to perceived environmental safety, and extend the literature by identifying personality characteristics that directly affect safety appraisals as well as interact with appraisals of safety-related information in the environment. These findings highlight the importance to move away from a framework of safety perceptions that regards environmental characteristics and personality characteristics as largely isolated contributing factors, and instead call for the adoption of a framework that acknowledges the intricate interaction between the person and the environment in the safety perception process.

Chapter 4

Temporal aspects of the safety appraisal process

4

This chapter is based on:

van Rijswijk, L., & Haans, A. (2013). Information processing in the blink of an eye: Safety and safety-related perceptions under varying presentation times. Meeting abstract: 10th Biennial Conference on Environmental Psychology, September 22-25, 2013, Magdeburg: Otto von Guericke University.

In the previous two chapters we have examined which informational cues from the environment are important for determining the safety of an environment, how these informational cues are used by the individual, and how the interaction between environmental-level and individual-level characteristics influence perceptions of environmental safety. In the current chapter, we aim to broaden our understanding by investigating temporal aspects of the safety appraisal process; how much time is required to achieve accurate appraisals of environmental safety?

The functionalist perspective on environmental perception emphasizes that the processing of environmental information has been instrumental to our survival, aiding the adaptive functioning of humans (and other organisms) in their environment (e.g., Brunswik, 1952; Gibson, 1979; Kaplan & Kaplan, 1989; Appleton, 1975; 1984; see Chapter 1). If there is merit in such an evolutionary model, stressing the importance of information processing and emphasizing that humans are exceptionally well-equipped to extract and process relevant information from the environment (e.g., Kaplan & Kaplan, 1989), we would expect that the function of (safety-related) environmental appraisals is optimal when the appraisal process is rapid, requiring minimal cognitive effort (see also Parsons, 1991). To our knowledge, there is currently no empirical work that investigates the time required to extract sufficient safety-relevant information from the environment to achieve accurate appraisals of the safety of outdoor environments. However, on a more general level, researchers have focused on thresholds for the processing and categorizing of complex natural scenes[1], and this body of literature may provide us with some insights into the broad time-course of scene gist recognition – insights that may also apply to the perception of environmental safety.

In one study, Fei-Fei and colleagues (Fei-Fei, Iyer, Koch, & Perona, 2007) presented participants with photographs of natural scenes using a number of limited presentation times (i.e., 27, 40, 53, 67, 80, 107, or 500ms) and asked participants to describe the scene in a free-recall session. As expected, participants' responses when the stimulus was viewed in a single glance (i.e., ≤ 107ms) were less elaborate than the responses obtained from participants that viewed the stimulus for 500ms. Yet, participants showed a remarkable ability to perceive and recall much object and scene-level information within a single glance. While low-level scene features (e.g., shading, shape) dominated responses at stimulus presentation times (SPTs) below 50ms, more abstract scene features (e.g., type of scene) were increasingly available to participants as SPTs increased above 50ms. These results are in line with previous findings, showing that people are generally able to perform accurate object detection in, and perform basic-level categorization (e.g., forest, beach) of, natural scenes within 150ms (e.g., Thorpe, Fize, & Marlot, 1996; Bacon-Macé, Macé, Fabre-Thorpe, Thorpe, 2005; Grill-Spector & Kanwisher, 2005; Greene & Oliva, 2009).

In the empirical work that characterizes the natural scene processing literature, basic-level categorization is commonly operationalized as the relatively concrete classification (e.g., forest, beach) that is typically attributed to a given categorization object by non-expert subjects (e.g., Hegdé, 2008). Yet, compared to basic-level categorization and object detection, the categorization of natural scenes with respect to safety may involve more complex information processing, integrating appraisals of a number of physical environmental characteristics (e.g., an appraisal of the extent to which the environment offers prospect to an observer). Recent work by Greene and Oliva (2009) investigated differences in rapid perception between such physical environmental characteristics, which they defined as spatial and functional properties of the environment, and basic-level categories. The authors employed a linear 3-up/1-down staircase method using steps of 10ms to establish participants' performance threshold for classifying natural scenes according to a number of basic-level categories and physical environmental characteristics (including concealment). The results indicated that perceptions of physical environmental characteristics were even more accessible than the perception of an environments' basic-level category (i.e., 75%-correct average threshold performance of 34ms and 50ms respectively). For example, the 75%-correct threshold performance for classifying the scenes with respect to concealment was only 35ms. Thus, these results suggest that physical environmental characteristics, including safety-related environmental characteristics (e.g., prospect, concealment, and entrapment), may also be rapidly perceived within a single glance.

In sum, in line with what we would expect on the basis of a functionalist information-processing approach to environmental perception, our discussion of the literature on the processing of complex natural scenes shows that people are capable of swiftly perceiving relevant environmental characteristics. Moreover, with respect to understanding the safety appraisal process, our discussion suggests that people are indeed well-equipped to rapidly assess safety-related environmental characteristics (e.g., the appraisal of concealment; see Greene & Oliva, 2009). What is still unclear, however, is what these findings imply for the time required to achieve accurate appraisals of environmental safety – appraisals that may both be more complex than the appraisal of physical environmental characteristics, and more dependent on subjective interpretations of the environment as compared to object detection and basic-level categorization tasks.

1 In the current discussion, natural scene refers to a real-life environment, as opposed to an experimentally contrived configuration of stimuli, and may encompass both natural environments (e.g., a forest) as well as man-made indoor and outdoor environments (e.g., an urban street).

Research aims

In the current chapter, we aim to gain a better understanding of the time required to extract sufficient environmental information to achieve accurate appraisals of the safety of an environment. In Study 4.1, we examine how much time participants require to confidently categorize scenes with respect to environmental safety and prospect if granted unlimited response time. Moreover, we explore potential difference in response time between appraisals of environmental safety and appraisals of prospect. In Study 4.2, we experimentally control and manipulate the presentation time of our stimuli, examining participants' accuracy in the categorization task under varying stimulus presentation times ranging from 17ms to 150ms.

Study 4.1

The first study was designed as a pilot study in which we aimed to get a first impression of the time required to make confident safety(-related) judgments. Participants were instructed to categorize environments with respect to perceived environmental safety and prospect without any procedural restrictions on response time. In this way, we could examine potential differences in response time between appraisals of environmental safety and appraisals of prospect. Based on our discussion of the literature on the rapid processing of physical environmental characteristics, and the idea that appraisals of environmental safety may need more complex information processing, we expected that participants would exhibit slower response times (RTs) when categorizing the stimuli with regard to environmental safety as compared to categorizing the stimuli with regard to prospect.

Method

Participants and design. We employed a two (categorization task: safety versus prospect) by two (task order: safety first versus prospect first) mixed repeated-measures design in which participants categorized 60 stimuli. Each participant viewed the complete stimulus set twice, once to categorize the stimuli with regard to the safety of the depicted environments, and once to categorize the stimuli with regard to the level of prospect. In addition to this within-subjects factor, the order in which participants evaluated the stimulus set on environmental safety and prospect (i.e., safety first or prospect first) was manipulated between participants. Our dependent variable was participants' response time.

Our sample comprised 30 participants (23 males and 7 females, M_{age} = 20.8, SD_{age} = 1.92, age range = 18 - 26 years). Participants were registered in the Eindhoven University of Technology's J.F. Schouten participant database and responded to an invitation to participate in a sequence of unrelated experiments. Participants required approximately 60 minutes to complete all experiments in the sequence and received €10,- as compensation for their effort. The present study was the first experiment in the sequence, and participants required approximately 15 minutes to complete the experiment.

Setting and apparatus. Participants were seated behind a desk in one of eight available cubicles. 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). Experiment instructions and stimuli were presented on a 19" color calibrated LCD monitor screen running at a 1600 pixels by 1200 pixels resolution and a 60Hz refresh rate. The experiment was presented on the monitor screen using the E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) running at a 640 pixels by 480 pixels resolution. We used a keyboard to record participants' responses to the stimuli.

Materials. We employed 60 stimuli depicting nocturnal urban environments, which were selected from our complete stimulus set of 100 photographs (see Chapter 2) on the basis of the evaluations of safety and prospect from Study 2.1. Since we would be using the same set for both environmental safety and prospect judgments, we calculated an average score from both the perceived environmental safety and the prospect evaluations for each of the 100 stimuli in our stimulus set. We then ranked the stimuli according to the resulting average safety-prospect score, and used the 20 highest ranking stimuli, the 20 lowest ranking stimuli, and the 20 moderately ranked stimuli (i.e., sampled from the central ranks) as stimuli in the current study. In this subset of 60 stimuli, evaluations of environmental safety and prospect were correlated with r = .80 and p < .001. Throughout the analyses of the current study, we may refer to stimulus category labels as 'safe' or 'unsafe'. In these instances, unless otherwise indicated, we refer to the stimulus categories based on the composite ranking of perceived environmental safety and prospect.

Procedure. Participants were welcomed into the laboratory, instructed to complete an informed consent form, and directed to one of the eight available cubicles. Before the experiment started, participants were randomly assigned to one of the two between-subject conditions (i.e., task order: safety first vs prospect first). The group of participants assigned to the first condition evaluated safety first (N = 15), while the participants assigned to the second group evaluated prospect first (N = 15).

The initial instruction screen informed each group of participants that the experiment was concerned with the perception of outdoor environments and that the goal of the experiment was to investigate how quickly people are able to make judgments about these environments. On the following instruction screen, participants were informed that during the experiment they would be presented with photographs of nocturnal urban environments and instructed to use the keys 'A' and 'L' on the keyboard to categorize each environment as safe [high prospect] or unsafe [low prospect]. Whether the 'A' key or the 'L' key indicated

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a safe [high prospect] environment was counterbalanced between participants.

Before the experimental trials, participants completed six practice trials in which they categorized daytime urban environments. At the beginning of each trial, a fixation cross was presented for 1500ms at the center of the screen. Next, a randomly selected stimulus was presented full-screen until the participant pressed either one of the assigned categorization keys on the keyboard. Following the practice trials, an instruction screen was presented in which the participants were reminded about the experimental procedure (e.g., "press the 'L' key to categorize the depicted environment as a safe environment"), and instructed to make their categorization judgments as quickly and accurately as possible. Next, participants responded to the 60 experimental trials. After finishing the first part of the experiment, an instruction screen informed participants that the second part of the experiment consisted of an analogous categorization task in which the participant was required to categorize the same stimulus set on prospect [safety]. At the end of the session of experiments, participants responded to two demographic questions about sex and age.

Results and discussion

No participants were identified as outliers (i.e., more than three standard deviations removed from group average) on average response time (RT; M_{RT} = 1175.41ms, SD_{RT} = 462.71ms, range = 602.68ms - 2511.03ms; aggregated over stimuli). Similarly, on the level of the stimuli, no outliers were identified on average RT (M_{RT} = 1175.41ms, SD_{RT} = 156.07ms, range = 828.2ms - 1471.1ms; aggregated over participants).

We used the *mixed* command available in the Stata 13.1 software package (StataCorp, 2013) to fit a linear mixed-effect model with categorization task (safety versus prospect) and task order (safety first versus prospect first) as fixed effects, participants and stimuli as crossed random effects, and RT as continuous dependent variable. The inclusion of participants and stimuli as random factors in the model allows for clustered correlations within each individual instance, and enables us to assess the contribution of each random factor to the total variance in RTs. Inspection of the variance components revealed that approximately 25% of the variance could be attributed to the participants, while a mere ~2% of the variance could be attributed to the stimuli. These findings are in line with the findings from the aggregated analyses presented above, where the range and standard deviation of average RTs was found to be much larger for participants than for stimuli.

After fitting the model, we used the *margins* and *pwcompare* commands available in the Stata 13.1 software package to calculate the marginal means and run Bonferroni corrected pairwise comparisons on average RTs between groups (see *Table 4.1* for the estimated marginal means for each condition). As expected, we found that participants responded

faster when categorizing stimuli with respect to prospect as compared to categorizing stimuli with respect to safety (M_{safety} = 1236.72ms, $M_{prospect}$ = 1114.11ms, SE_{MM} = 84.65ms; C = -122.6, $SE_{contrast}$ = 23.58, z = -5.20, p < .001). However, while no main effect was found for the order in which participants completed the two categorization tasks (M_{safety_first} = 1241.92ms, $M_{prospect\_first}$ = 1108.90ms, SE_{MM} = 117.42ms; C = -133.04, $SE_{contrast}$ = 164.44, z = -.81, p = .42), the analysis did reveal a significant interaction effect (β = 285.24, SE = 47.15, z = 6.05, p < .001; see *Figure 4.1*). Pairwise comparisons between all factorial groups revealed that there was a significant difference in average RT between the safety and prospect categorization task when the safety categorization task was the first categorization task (C = -265.22, $SE_{contrast}$ = 33.34, z = -7.95, p < .001). We did not find any other significant differences between groups (all zs ≤ |1.66|, all ps ≥ .58).

	Task order	
	Safety first	Prospect first
Safety	1374.54 ms	1098.89 ms
Prospect	1109.32 ms	1118.90 ms

Table 4.1. Estimated marginal mean response times in milliseconds for all combinations of the between-subject (task order) and within-subject (categorization task) factors in Study 4.1.

Thus, participants were significantly slower in their categorization of the stimuli with respect to safety as compared to their categorization of the stimuli with respect to prospect when the safety categorization task was the first of the two categorization tasks. These results are in line with the idea that the appraisal of environmental safety is more complex, depending on the integration of multiple environmental characteristics (such as prospect). However, when participants categorized prospect first, the difference in RT between the two categorization tasks disappeared. While the appraisal of environmental safety may be achieved through a number of different appraisals of safety-related characteristics of the environment (i.e., vicarious mediation, see Chapter 1), our results suggest that when prospect was made salient, participants tended to use prospect as a proxy for inferring the safety of an environment.

One potential limitation for interpreting the reported conditional response latencies is that we measured these response latencies using a keyboard that was not specifically designed to accurately record responses at the millisecond level. Such an imprecise response device may, for example, increase the error variability of the reported response latencies, or add a constant amount of additional response latency (or lag) to each recording. However, although we did not log measurement precision in our study, the typical polling rate associated with modern input devices that are connected via the USB port is 125Hz (i.e., the computer checks whether a key has been pressed roughly every 8ms), which, as a maximum on measurement inaccuracy due to polling rate, is relatively small in comparison to the reported magnitudes of the aggregated mean RTs and their associated standard deviations. In addition, Damian (2010) has argued that for well-powered studies, the increases in error variability associated with relatively imprecise response devices is likely to be negligible as compared to the variability that is associated with human performance when analyzing aggregated response latencies. Nonetheless, to increase measurement precision in the follow-up study (Study 4.2), we used a dedicated response device that is able to measure reaction times at the millisecond level.

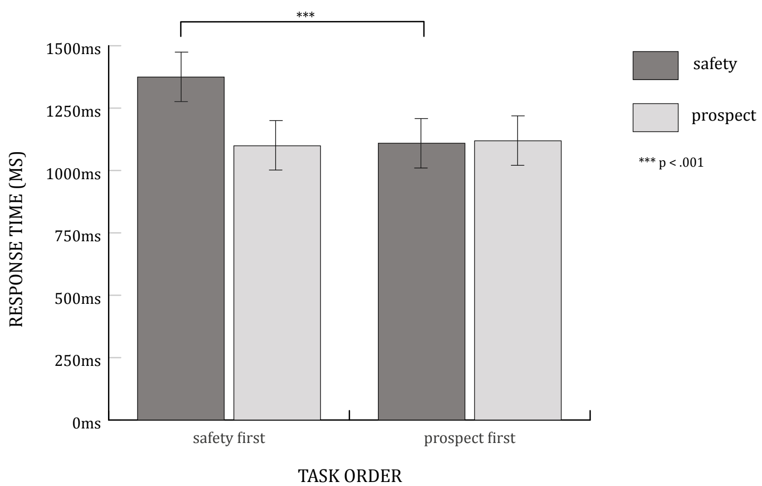

Figure 4.1. Estimated marginal mean response times and error bars for each experimental condition (in milliseconds).

Response accuracy. For the purpose of the categorization task used in the current studies, we utilized a subset of stimuli from the stimulus set described in previous chapters, thus allowing us to measure participant's categorization accuracy[2] by comparing their

2 In our view, the consistent findings showing relatively stable evaluations across participants within and between the studies presented in this thesis thus far, do warrant the (prudent) use of accuracy terminology in the current chapter. However, as appraisals of perceived environmental safety and the safety-related characteristics of the environment tend to be dependent substantially on individual characteristics as well as on characteristics of the environment (see Chapter 2 and Chapter 3), we should be clear that the term accuracy here does not reflect a comparison with an absolute and objectively established value, but should be interpreted as referring to the relative agreement between samples of subjective evaluations.

categorization response to a pre-defined stimulus category based on previous evaluations obtained in Study 2.1.

We calculated response accuracy (RA; 0 = incorrect, 1 = correct) by comparing categorization response (i.e., safe / unsafe) with stimulus category for the stimuli that were classified as belonging either to the safe or unsafe category based on the ratings from Study 2.1 (N = 40). Importantly, although both the participants from Study 2.1 and the current study were sampled from the J. F. Schouten participant database, there was no overlap in participants between the two samples.

A χ^2 goodness of fit test showed that participants' responses deviated from the expected equality of response proportions with $\chi^2(1) = 266.78$, and $p < .001$, exhibiting a tendency to categorize stimuli positively (i.e., safe or high prospect; see *Table 4.2*). Of the 3600 categorization responses observed, 64% were categorized as safe. Similar patterns were found for both the safety ($\chi^2(1) = 181.77$, $p < .001$) and the prospect ($\chi^2(1) = 92.48$, $p < .001$) categorization tasks separately (see *Table 4.2*).

	Categorization task		
Response	Safety	Prospect	Total
Safe [high prospect]	1186 (66%)	1104 (61%)	2290 (64%)
Unsafe [low prospect]	614 (34%)	696 (39%)	1310 (36%)
Total	1800	1800	3600

Table 4.2. Categorizations responses from Study 4.1 by categorization task.

The average RA of one participant was more than three standard deviations from the mean average RA across all participants. However, the average accuracy across all participants, including the outlier, was very high (M_{RA} = .81, SD_{RA} = .07, range = .55 - .90). These results suggest that there was considerable agreement between the responses obtained with the dichotomous categorization task in the current study, and the responses obtained in Study 2.1 using five-point response category format items.

Although the average RA on the stimulus level was the same as the average RA on the level of the participants, the standard deviation around the mean was twice as large for stimuli (M_{RA} = .81, SD_{RA} = .17, range = .13 - .98), indicating larger variability in average RA between stimuli as compared to the variability in average RA between participants. Inspection of the ten lowermost RAs (range = .13 - .75), revealed that stimuli from the unsafe stimulus category were disproportionately represented in this set, with nine out of ten of the stimuli associated with low RAs stemming from the unsafe stimulus category. Moreover, splitting the RAs according to stimulus category (see *Table 4.3)*, revealed that the average RA for the unsafe stimulus category, albeit still high, was significantly lower than the average RA for the safe stimulus category (M_{safe} = .88, SD_{safe} = .09, M_{unsafe} = .74, SD_{unsafe} = .20, $F(1,39) = 7.98$, $p = .008$, $R^2_{adj} = .15$). We will discuss these findings pertaining to response accuracy in more detail in the general discussion.

	M	SD	Min	Max
Overall	.81	.17	.13	.98
Safe category only	.88	.09	.60	.98
Unsafe category only	.74	.20	.13	.95

Table 4.3. Estimated marginal means for response accuracy within and across stimulus categories in Study 4.1.

In sum, our results demonstrated that participants were able to achieve confident judgments in a relatively short amount of time (i.e., ~ 1 second), corroborating the idea that we do not need an extensive amount of time to retrieve relevant environmental information from a stimulus to make a judgment about the environment. Moreover, our results indicate that appraisals of environmental safety may require more time than appraisals of prospect, suggesting that environmental safety appraisals may depend on the integration of multiple appraisals of safety-related environmental characteristics.

Study 4.2

Study 4.2 was designed to provide a more rigorous experimental test of the time required to extract sufficient relevant environmental information to achieve accurate judgments of environmental safety. Whereas the design of Study 4.1 allowed participants, in principle, unlimited time to extract information and reach a decision, in Study 4.2 we experimentally controlled and manipulated the time participants were allowed to view the stimuli. We varied the presentation time of our stimuli in nine steps between 17ms and 150ms, and for each level of stimulus presentation time we measured participants' accuracy on the same dichotomous categorization task we used in the previous study. Given that there is, to our knowledge, no empirical work investigating the temporal aspects of environmental safety appraisals, and the currently presented studies are thus largely explorative in nature, we did not have an a priori expectation about the pattern of results for each level of our stimulus presentation time manipulation.

However, previous findings do indicate that appraisals of (safety-related) physical characteristics of the environment may be achieved as rapidly as ~35ms (Greene & Oliva, 2009). Given the complex nature of environmental safety appraisals, which are expected to depend on the integration of multiple appraisals of physical characteristics of the environment, we generally expected that participants' performance in the safety categorization task would be better under slower SPTs as compared to faster SPTs. The specification of the cutoff point at which sufficient information may be extracted to achieve an accurate appraisal of environmental safety remained an empirical question.

Method

Participants and design. We employed a within-subjects design in which participants categorized a selection of stimuli from our stimulus set (see Chapter 2) under various stimulus presentation times (SPTs). The nine levels of our independent variable (i.e., SPT) ranged from 17ms to 150ms[3] in equal steps of approximately 17ms, which corresponded to the 60Hz refresh rate of the monitor screen used in the experiment. In each trial of the experiment, participants made a dichotomous judgment about the safety of the depicted environment (i.e., safe or unsafe). Our dependent variable was the accuracy of participants' evaluation of the safety of the depicted environment.

Our sample comprised 53 participants (28 males and 25 females, M_{age} = 21.75, SD_{age} = 2.98, age range = 18 - 31 years). The participants were registered in the Eindhoven University of Technology's J.F. Schouten participant database and responded to an invitation to participate in our study. Participants required approximately 15 minutes to complete the experiment and received €3,- as compensation for their participation.

Setting and apparatus. The current experiment was performed in the same experimental setting and with the same apparatus as Study 4.1. However, in the current experiment, we used a serial response box (Psychology Software Tools, Pittsburgh, PA) to record participants' responses to the stimuli. The serial response box is a dedicated response device capable of recording responses at the millisecond level.

Materials. The stimulus set comprised the 15 most safe and 15 most unsafe stimuli from our stimulus set (see Chapter 2), based on the evaluations of perceived environmental safety from Study 2.1. The stimuli depicted nocturnal urban environments and were devoid of other people or animals.

Procedure. Participants were welcomed into the laboratory, instructed to complete an informed consent form, and directed to one of the eight available cubicles. The experiment was presented on the monitor screen using the E-Prime 2.0 software. Participants were

3 The upper limit of 150ms was based on two pre-tests in which we manipulated stimulus presentation times ranging from 150ms to 1500ms. In line with what we would expect on the basis of the natural scene processing literature discussed in the introduction of the current chapter, these pre-tests showed no improvement on categorization accuracy beyond the lower limit of 150ms.

informed that the experiment was concerned with perceived safety in outdoor environments and that the goal of the experiment was to investigate how quickly people are able to make safety judgments. On the next screen participants were informed that during the experiment they would be presented with photographs of nocturnal urban environments for very short durations, and instructed to use the serial response box to categorize the depicted environment either as a more unsafe environment or as a more safe environment. Next, participants completed 18 practice trials in which they categorized daytime urban environments, before completing 90 experimental trials. The 90 experimental trials were divided over three experimental blocks each containing all 30 stimuli (see Materials section). Within each experimental block, the stimuli were presented in random order. Each stimulus presentation was paired with a randomly selected level of SPT that was counterbalanced within stimulus. Thus, although each participant viewed each stimulus a total of three times, the presentation time was different for each presentation.

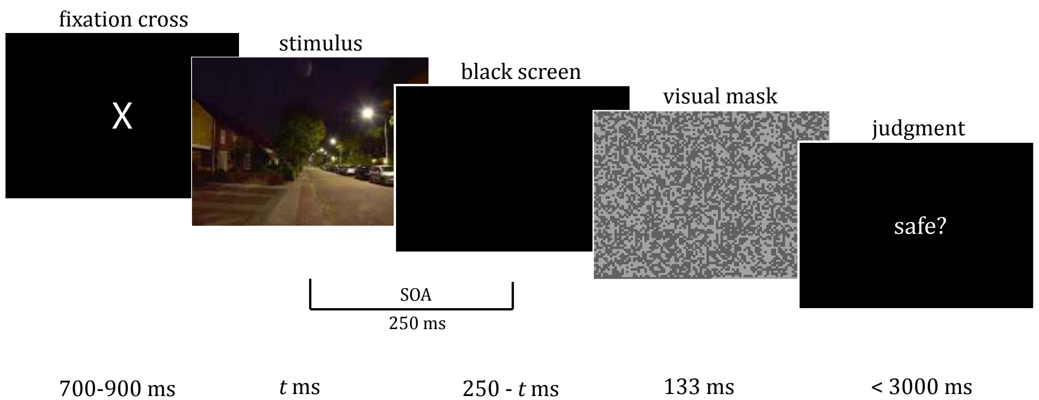

Figure 4.2. The procedure of one experimental trial in Study 4.2.

Each experimental trial consisted of five phases (see *Figure 4.2*). First, participants were presented with a fixation cross at the center of the screen for a random duration between 700ms and 900ms. Next, the selected stimulus was presented full-screen for the duration of the selected SPT[4], followed by a black screen and a visual masking procedure. The total time between stimulus onset and the onset of the visual mask (i.e., the stimulus onset asynchrony – SOA) was kept constant at 250ms. The duration of the black screen

4 The E-Prime software provides a measured and reported timing precision with a standard deviation of < 0.5ms. Additional measures we took to maximize timing precision included (a) pre-releasing of objects preceding critical objects, (b) synchronizing with refresh cycle of the monitor screen (i.e., 17ms), and (c) running the software at highest priority during the experimental session.

was thus dependent on the SPT associated with the experimental trial. The visual masking procedure consisted of a rapid succession of four greyscale random noise images of varying resolution presented for 33ms each. This visual masking procedure was implemented to impair further processing of the image by erasing the visual memory (see Bacon-Macé et al., 2005). After the visual masking procedure, the final screen of each experimental trial requested participants to categorize the depicted environment by pressing either the leftmost button or the rightmost button on the serial response box. Whether the left or the right button indicated a safe environment was counterbalanced between participants. The participants were allowed a maximum response time of 3000ms before automatically continuing to the next trial.

After completing all 90 experimental trials, participants completed the last part of the experiment which was designed to check participants' recognition of the stimuli used in the experimental trials. Participants viewed a total of nine stimuli and indicated for each stimulus whether they recognized that stimulus from the experimental trials and how confident they were of their recollection. We measured confidence using a five-point response category format item (i.e., "How confident are you of your decision?"), ranging from (1) "very uncertain" through (3) "neither uncertain nor confident" to (5) "very confident". The nine stimuli in the recognition task consisted of three random stimuli from the safe category, three random stimuli from the unsafe category, and three random stimuli from a set of 15 distractor stimuli not used in the current experiment. After completing the last part, participants responded to three demographic questions about sex, age, and current residence.

Results and discussion

Response accuracy (0 = incorrect, 1 = correct) was computed by comparing the categorization response (i.e., safe or unsafe) with the stimulus category (i.e., safe or unsafe) based on the safety evaluations from Study 2.1. Although both the participants from Study 2.1 and the current study were sampled from the J. F. Schouten participant database, there was no overlap in participants between the two samples. A comparison between the original ratings based on the five-point response category format items from Study 2.1 with the probability of being categorized as safe in the categorization task in the current study showed the two measures were highly correlated ($r = .91, p < .001$), suggesting that there was high agreement between these two measures of perceived environmental safety.

There were no outliers (≥ 3 *SD*s from group average) on average RA ($M_{RA} = .78$, $SD_{RA} = .07$, range = .63 - .96) or average RT ($M_{RT} = 410.82$ms, $SD_{RT} = 142.39$ms, range = 113.33ms – 733.92ms) on the level of the participants (aggregated over stimuli and SPT). There was no speed-accuracy trade-off ($r_{RT\text{-}RA} = -.11, p = .44$). In the same way, we found no outliers on average RA (M_{RA} = .78, SD_{RA} = .18, range = .36 - .96) or average RT (M_{RT} = 410.41ms, SD_{RT} = 49.32ms, range = 290.44ms – 485.30ms) on the level of the stimulus (aggregated over subjects and SPT).

In agreement with the results from Study 4.1, a χ^2 goodness of fit test showed that participants' responses deviated from the expected equality of response proportions with $\chi^2(1)$ = 185.70, and p < .001, again exhibiting a tendency to categorize stimuli positively. Approximately 60% of the 4860 observations were categorized as safe. However, a further analysis of the distribution of categorization responses for each level of SPT revealed that whereas all SPT levels above 17ms indeed demonstrated the tendency towards safety (all $\chi^2(1)$s ≥ 18.05, all ps < .001), the categorization responses for the 17ms SPT level were more evenly matched at 50% ($\chi^2(1)$ = .02, p = .898). Closer inspection of the ten stimuli associated with the lowermost accuracies (range = .36 - .78) again revealed that nine out of the ten stimuli in this subset were stimuli from the unsafe stimulus category. Additionally, there was a significant correlation between average RT and average RA (r = -.67, p < .001) on the level of stimuli, such that increased average RT was associated with a lower average RA. These results suggest that some stimuli were more difficult to categorize than other stimuli. We explore this potential issue more thoroughly after our main analysis.

Recognition check. With respect to the recognition of the stimuli, we found that participants were very well able to identify which stimuli were used in the experimental trials (82% correctly identified) and which were not (76% correctly identified), and that participants were also confident about the correctness of their responses ($M_{confidence}$ = 3.62, $SD_{confidence}$ = .47 for experimental stimuli; $M_{confidence}$ = 4.09, $SD_{confidence}$ = .40 for distractor stimuli). Thus, the use of short SPTs did not seem to affect the recognition of stimuli used in the experiment.

Main analysis. We used the *meqrlogit* command available in the Stata 13.1 software package to fit a logistic linear mixed-effect model with SPT level as fixed effect, participants and stimuli as crossed random effects, and RA (0 = incorrect, 1 = correct) as binary dependent variable. After fitting the model, the marginal means were estimated from the model using the *margins* command (see *Table 4.4*). In contrast to what we expected, participants demonstrated above chance-level (i.e., RA > .50) accuracy for all nine SPT levels (all LLCIs ≥ .74). In addition, pairwise comparisons between SPT levels using a Bonferroni correction revealed that there were in fact no significant differences in average RA between all levels of SPT (all zs ≤ |1.52|, all ps > .99).

SPT	M	SE	LLCI	ULCI
17 ms	.82	.04	.74	.89
33 ms	.85	.03	.78	.91
50 ms	.83	.03	.77	.90
67 ms	.82	.04	.74	.89
83 ms	.83	.03	.76	.90
100 ms	.82	.04	.75	.89
117 ms	.84	.03	.78	.91
133 ms	.85	.03	.79	.91
150 ms	.82	.04	.75	.89

Table 4.4. Estimated marginal means (M), standard errors (SE), and lower level (LLCI) and upper level (ULCI) confidence intervals for each stimulus presentation time (SPT).

Exploratory analyses. Similar to the results of our analyses on the level of the stimuli in Study 4.1, we found that in the current experiment disproportionally more stimuli from the unsafe stimulus category, as compared to stimuli from the safe stimulus category, were associated with the lowermost average RAs across stimuli. A comparison between the average RAs associated with both stimulus sets again revealed that the average RA for the unsafe stimulus category was significantly lower than the average RA for the safe stimulus category (M_{safe} = .87, SD_{safe} = .05, M_{unsafe} = .68, SD_{unsafe} = .22, F(1,29) = 11.56, p = .002, R^2_{adj} = .27). Additionally, we again found an overall tendency to categorize the stimuli as safe. These results suggest that the stimuli from the unsafe stimulus category were more difficult to categorize correctly than the stimuli from the safe stimulus category. *Figure 4.3* illustrates differences in categorization difficulty between the stimuli from the unsafe category and the stimuli from the safe category; while stimuli from the safe category were roughly similar in difficulty, stimuli from the unsafe stimulus category that were evaluated just below the midpoint of the safety rating scale in Study 2.1 were more ambiguous as compared to the stimuli from the unsafe stimulus category evaluated at the lower end of the safety rating scale. Given these apparent discrepancies between stimulus categories, it may be informative to repeat our main analysis for the two stimulus categories separately (see *Table 4.5*; the results of these analyses are also plotted against the original results in *Figure 4.4*).

Safe stimulus category. We fitted a logistic linear mixed-effect model using the same procedure as in the main analysis, and estimated the marginal means (see *Table 4.5*). Inspection of the 95% confidence intervals again revealed that for all SPT levels, participants were able to categorize the stimuli above chance-level (all LLCIs ≥ .73). However, pairwise comparisons between SPT levels using a Bonferroni correction now revealed that the average RA for the lowest SPT level (i.e., 17ms) was significantly lower than the average RAs of the other SPT levels (all zs ≥ 3.50, all ps ≤ .017). We found no significant differences in average RA between all other levels of SPT (all zs ≤ |1.81|, all ps > .99).

Unsafe stimulus category. We again fitted a logistic linear mixed-effect model and estimated the marginal means (see *Table 4.5*). The 95% confidence intervals revealed that, albeit to a lesser extent than stimuli from the safe stimulus category, participants were able to categorize the stimuli above chance-level (all LLCIs ≥ .56). Unexpectedly, however, Bonferroni corrected pairwise comparisons between SPT levels revealed that the average RA for the 17ms SPT level was significantly *higher* than the average RA for the 50ms ($C = -.76$, $SE_{contrast} = .23$, $z = -3.29$, $p = .036$), the 83ms ($C = -.87$, $SE_{contrast} = .23$, $z = -3.87$, $p = .004$), and the 150ms ($C = -.84$, $SE_{contrast} = .23$, $z = -3.62$, $p = .011$) SPT levels. We found no significant differences in average RA between all other levels of SPT (all $zs \leq |3.19|$, all $ps \geq .051$).

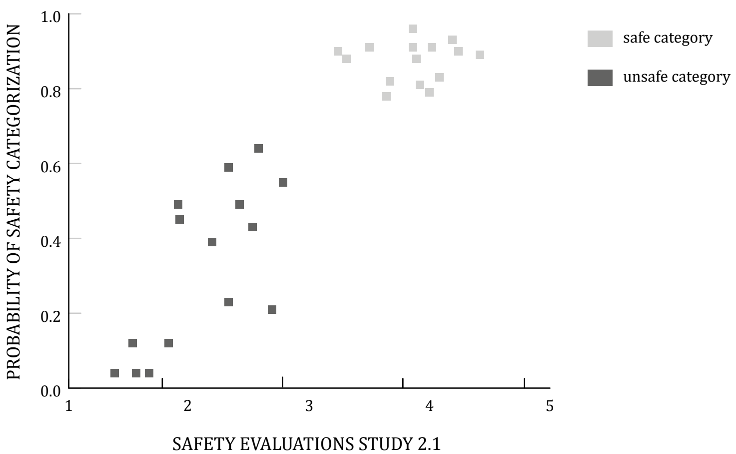

Figure 4.3. Safety evaluations from Study 2.1 plotted against the probability of being categorized as safe in Study 4.2 for each stimulus from the safe and the unsafe stimulus categories.

	Safe category				Unsafe category			
SPT	M	SE	LLCI	ULCI	M	SE	LLCI	ULCI
17 ms	.81	.04	.73	.88	.87	.05	.76	.97
33 ms	.91	.02	.87	.96	.81	.07	.67	.94
50 ms	.93	.02	.90	.97	.75	.08	.59	.91
67 ms	.91	.02	.83	.95	.65	.08	.59	.92
83 ms	.94	.02	.91	.97	.73	.09	.56	.90
100 ms	.92	.02	.87	.96	.75	.08	.59	.92
117 ms	.93	.02	.90	.97	.77	.08	.62	.93
133 ms	.94	.02	.91	.98	.77	.08	.62	.93
150 ms	.93	.02	.89	.97	.73	.09	.56	.90

Table 4.5. Estimated marginal means (M), standard errors (SE), and lower level (LLCI) and upper level (ULCI) confidence intervals for each stimulus presentation time (SPT) for each stimulus category.

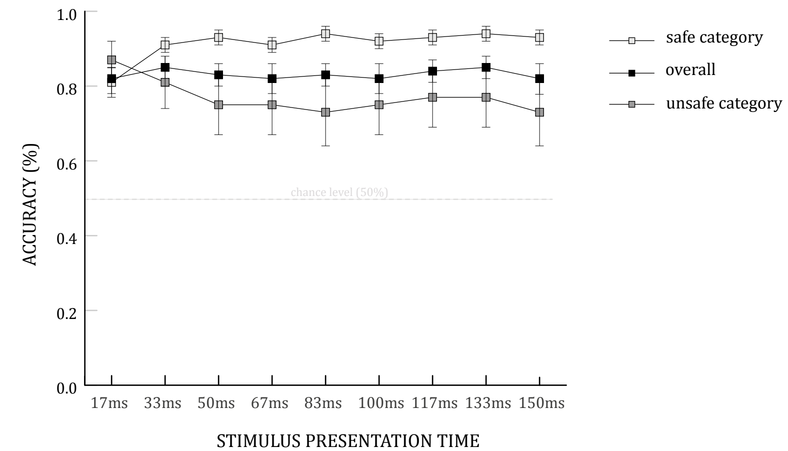

Figure 4.4. Estimated marginal means and error bars for response accuracy at each SPT level across stimulus categories.

General discussion

In the current chapter, we described two studies in which we explored temporal aspects of safety and safety-related appraisals of the environment. Taking a functionalist perspective, elaborating on the importance of rapid information processing for environmental perception, we expected that people would, in general, be capable of quickly assessing the safety of their environment. This proposition was in line with results from the broader natural scene processing literature showing that people are capable of extracting and recalling much scene-level information from an environment in a single glance. Indeed, our results from both studies corroborated the idea of the rapid nature of safety(-related) environmental appraisals. In Study 4.1, we found that participants, when instructed to respond as quickly and accurately as possible while maintaining confidence in their judgments, categorized stimuli relatively fast with respect to environmental safety and prospect (~1 second). Moreover, the results from Study 4.2 revealed that participants were capable of achieving high accuracy in the categorization task even when the stimuli were merely presented for 17ms (with a total processing time of 250ms). In addition, the results from Study 4.1 showed that appraisals of environmental safety require more time as compared to appraisals of safety-related characteristics of the environment (e.g., prospect).

While these general results are in line with the proposition that people are capable of rapidly assessing the safety of their environment, a more specific conclusion with respect to the time course of safety appraisals is more difficult to infer from the results of the two studies presented in the current chapter. One reason is that even though we manipulated the time the stimuli were presented on the screen, we kept the time from the onset of the stimulus until the visual masking procedure constant at 250ms. Thus, irrespective of the interval in which actual sensory information was available to the visual system, the total processing time, including the processing of information available from visible persistence of the stimuli or from iconic memory, was constant between all levels of stimulus presentation time. As a consequence, there may have in fact only been slight differences in available information between our levels of presentation times – a line of reasoning that may provide a feasible alternative explanation for the somewhat unexpected finding that even at the fastest stimulus presentation times participants performed very well on the categorization task. Future research may focus on testing this alternative explanation, for example by keeping stimulus presentation time constant and experimentally manipulating the time between stimulus onset and visual masking (i.e., stimulus onset asynchrony), or by applying visual masking procedures directly after different levels of stimulus presentation times. Still, the current results do provide compelling evidence that people are remarkably capable of extracting relevant information to achieve accurate judgments of environmental safety.

Explorative analyses

In our explorative analyses, we performed our analysis of participants' accuracy across the various stimulus presentation time levels separately for the safe and unsafe stimulus categories (see *Table 4.5* and *Figure 4.4*). In contrast to the results obtained from the analysis across both stimulus categories, we found contrasting response patterns for each stimulus category at the fastest stimulus presentation time level. For the safe stimulus category, participants performed significantly worse on the categorization task when the stimulus was presented for only 17ms as compared to all other levels of stimulus presentation time. In contrast, the results with respect to the unsafe stimulus category showed a (partially) opposite pattern, in which participants performed *better* at the fastest stimulus presentation time level as compared to some other levels of stimulus presentation time (i.e., 50, 83, and 150ms).[5]

While more research is needed to replicate these specific response patterns, we may potentially explain these patterns by considering Simpson's (1996) notions about the default cognitive frameworks that people apply when making appraisals of danger and safety. Simpson argued that the ambiguous nature of our objective environment merely provides clues about danger to an observer, and that the environmental context may activate different

5 In contrast to participants' performance at 17ms in the safe stimulus category, the performance at 17ms for the unsafe stimulus category was more haphazard, and not significantly better than the performance at all other SPT levels. However, visual inspection of both performance patterns as displayed in *Figure 4.4* does reveal that the general performance patterns between the stimulus categories are similar (albeit opposite). Our discussion focuses on these general patterns.

cognitive frameworks from which people interpret this ambiguous information. For example, traveling at night through a notoriously dangerous area of a large city activates a cautious cognitive framework, in which the default assumption is that everything is unsafe, unless proven safe. In contrast, more safe contexts activate a confident cognitive framework, in which the default assumption is that everything is safe.

The adoption of a specific interpretational framework may not only depend on such extraneous preconceptions about the environment, but also on the currently available informational cues to achieve confident environmental safety appraisals in unknown and ambiguous environments. For example, if people feel like they have sufficient information to make a confident assessment of an environment, they may adopt a confident interpretational framework, assuming a safe environment until proven otherwise, and we would expect people to err on the 'safe' side when confronted with ambiguous information. On the other hand, when the available information is insufficient to make confident environmental appraisals of safety, we would expect that people will adopt a cautious interpretational framework, and, as a result, will err on the 'unsafe' side when confronted with ambiguous information. Such an interpretation is in line with the findings presented thus far, both with participants' high overall performance – reflecting the availability of sufficient information to achieve an accurate appraisal of environmental safety – as well as with the slight tendency towards categorizing stimuli as safe – reflecting errors on the 'safe' side for ambiguous stimuli.

More importantly, if a cautious interpretational framework is adopted as a result of insufficient information, we would expect that participants in our categorization task performed worse on ambiguous stimuli from the safe stimulus category, and performed better on ambiguous stimuli from the unsafe category. Indeed, we found that participants' slight tendency to categorize the stimuli as safe was absent at the 17ms SPT level, and that participants performance for the safe category was decreased relative to the other SPT levels, while participants' performance for the unsafe category was increased relative to the other SPT levels. Thus, while the overall information available to participants at the 17ms SPT level may have been sufficient to ensure a high performance that was indistinguishable from performance at the other SPT levels, it may have been sufficiently insufficient for a confident interpretational framework to replace a cautious interpretational framework. Further research is needed to empirically investigate the validity of such a differential interpretational framework perspective on environmental safety perception.

Measuring environmental safety

Whereas the previous empirical chapters presented studies in which we measured perceived environmental safety using five-point response category format items, the current chapter presented two studies in which we measured perceived environmental safety (and prospect) using a dichotomous categorization task. The use of multiple methods for measuring our main concept of interest thus allows us to compare responses and examine the agreement between our different measures of perceived environmental safety. If the agreement between measures is high, we would expect a tendency for participants to categorize the stimuli according to the predefined stimulus category that was based on the ratings from Study 2.1 (i.e., a high response accuracy in the categorization task). In contrast, we would expect a tendency for participants to categorize the stimuli erroneously (i.e., a low response accuracy) if the agreement between measures is low.

Both studies presented in the current chapter showed considerable agreement with previous measures in terms of participants' response accuracy for categorizing the stimuli with respect to environmental safety. In Study 4.1, in which participants were allowed some time to view the stimuli, we found an ~85% response accuracy with respect to the safety categorization task, and an ~80% response accuracy with respect to the prospect categorization task. Moreover, even under the restricted conditions that participants were allowed to view the stimuli in Study 4.2, the overall accuracy of the safety categorization task was ~80%. In addition, the results from Study 4.2 showed that the original ratings and the results from the dichotomous categorization task were highly correlated. Thus, while the type of measures that employ multiple-point response category items are known to be vulnerable to a number of potential response biases (e.g., Daamen, 1991; Poulton, 1989; Fotios, Cheal, Uttley, Castleton, & Qasem, 2015), our results suggest that the responses obtained from using five-point response category format items are highly similar to the responses obtained from using a dichotomous categorization task.

Still, although the agreement indicates that participants' responses were robust across our different measures of perceived environmental safety, a dichotomous categorization task may not be free from similar or additional response biases. To illustrate, further examination of participants' responses in both studies revealed a tendency in response patterns that was biased in favor of categorizing the stimuli as safe. In Study 4.1, 66% of the stimuli were categorized as safe, and in Study 4.2, 61% of the stimuli were categorized as safe. Furthermore, our analysis on the stimulus level revealed that the stimuli from the unsafe stimulus category were disproportionally represented among the lowermost response accuracies in both studies. Splitting the analysis over the two stimulus categories additionally revealed that there was a discrepancy between the average response accuracies; whereas the average response accuracy for the safe stimulus category was as high as ~90%, the average response accuracy for the unsafe stimulus category was substantially lower at ~75%. Taken together, these results suggest that the stimuli from the unsafe category were more difficult to categorize 'correctly' as compared to the stimuli from the safe category (see also Figure 4.3).

A potential explanation may be that our five-point response category format measures in Study 2.1 were affected by a range bias. Range bias occurs as people tend to utilize the full range of a measurement scale to indicate the relative differences between items in an evaluation set (Daamen, 1991; Fotios et al., 2015). Even though these evaluation objects, as a sample of the total population of evaluation objects, may not embody the full range of a certain evaluation criterion, the objects that represent the largest differences *within the evaluation set* tend to be assigned to the extremes of the scale range. Thus, the environments that comprised our unsafe stimulus category because they were evaluated as 'unsafe' in Study 2.1, may in fact not have been very unsafe when considering the total population of environments, and consequently more difficult to categorize 'correctly'. Indeed, a recent study by Fotios and colleagues demonstrated this range bias in people's evaluations of environmental safety using our complete stimulus set and five-point response category format measures (Fotios et al., 2015). Future research may be directed at investigating the implications of a range bias in subjective evaluations of environmental safety, and compare the responses obtained from our measures with other, ostensibly more bias-free measurement paradigms (e.g., a pairwise comparison paradigm; see Fotios & Houser, 2009).

Limitations

In our discussion of the results in the previous sections, we have already touched upon some potential limitations of the current set of studies. However, on a more general level, two additional limitations may be identified. First, our results may overestimate the speed with which people seem to achieve accurate appraisals, as the use of a rather homogenous set of stimuli (i.e., nocturnal urban environments from the Eindhoven region) in our categorization tasks may have decreased the potential range of relevant environmental information, thus facilitating rapid information processing.

Second, the participants in our set of studies were seated in a controlled laboratory environment and performed a categorization task that focused them completely on making decisions about safety(-related environmental characteristics). We may suppose that outside the laboratory the amount of information and the range of potential issues that require one's attention is much larger. The amount of cognitive resources available for the processing of safety-relevant information may thus be reduced, and, as a result, rapid safety perception may be impaired. Consequently, our results may underestimate the actual time required for achieving accurate appraisals of environmental safety. Although we have argued that the perception of environmental safety is expected to be rapid, requiring little cognitive effort, future research may investigate how cognitive resources affect rapid perceptions of environmental safety, for example by measuring accuracy on a categorization task while limiting the amount of cognitive resources available to participants.

Conclusion

The set of studies presented in the current chapter extend the literature on temporal aspects in natural scene processing, providing evidence for the notion that people are capable of rapidly extracting the relevant environmental information to achieve accurate perceptions of environmental safety. Additionally, the high agreement between the measures of perceived environmental safety employed in the current chapter and the measures we employed in previous chapters indicate that our measurement of perceived environmental safety is robust across different methods. These latter results suggest that the rapid dichotomous categorization paradigm employed in Study 4.2 may be successfully utilized to study environmental (safety) perceptions.

Chapter 5

Located information seeking

This chapter is based on:

van Rijswijk, L., & Haans, A. (2015). Exploring a new paradigm for investigating localized information seeking in the safety perception process. Meeting abstract: 11th Biennial Conference on Environmental Psychology, August 24-26, 2015, Groningen: Rijksuniverstiteit Groningen.

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We have proposed and investigated a framework for understanding perceptions of environmental safety through the selection and weighing of informational cues in the proximate environment. However, the studies presented thus far have mainly focused on understanding *which* environmental information people use to infer the safety of an environment (see Chapter 2 and Chapter 3), and we have not yet considered whether these informational cues may be weighted differently depending on *where* the information is located in the physical space that surrounds us. For example, consider a pedestrian and a cyclist travelling through the same environment. The pedestrian – covering between 1 and 1.5 meters every second – may base safety judgments primarily on cues that are located nearby, weighting less heavily information that is located far ahead and thus outside of the pedestrian's immediate concern. This particular utilization, or weighting, of distant and nearby cues may not be adaptive to the cyclist. After all, information that is far ahead, and thus not immediately relevant to the pedestrian, may be crucial for the cyclist who is perhaps traveling at a speed of four to five times that of the pedestrian. In other words, whereas the pedestrian may be more attuned to information that is physically nearby, the cyclist may be more attuned to information in the distance.

In the current chapter, we extend our conception of environmental safety perception by examining more explicitly how the environment is conceptualized from a psychological point of view. We explore the idea that the processing of safety-related informational cues from the environment is adapted to safety-relevant subdivisions of the physical space that surround us. In other words, we expect that pedestrians, when making an appraisal of environmental safety, will not apportion equal importance to all safety-related information regardless of where in the environment it is located, but will instead be more attuned to information from those parts of physical space that are directly relevant to their immediate safety.

While there currently is, to our knowledge, no empirical work that has directly investigated the influence of differentially spaced information on the appraisal of environmental safety, a recent study by Haans and de Kort (2012), investigating the effect of different lighting distributions on safety perceptions, provides some interesting findings relevant for our current discussion. In this study, participants were presented with three different lighting distributions on a controlled test bed on the campus of the Eindhoven University of Technology: a spotlight distribution (i.e., most of the light in the immediate surroundings of the participants, and much less on the road ahead), a dark spot distribution (i.e., most of the light on the road ahead, and not so much in the immediate surroundings of the participants), and an even distribution typically found in conventional street lighting implementations. For each distribution, participants completed questionnaires measuring perceived environmental safety and appraisals of the safety-related environmental characteristics (i.e., prospect, concealment, and entrapment). While it was expected that participants would prefer the lighting distribution that provided a good overview of the road ahead without too much personal exposure (i.e., the dark spot distribution), the results showed a preference for the spotlight distribution. More importantly, participants were inclined to assign higher evaluations of prospect and lower evaluations of concealment and entrapment to the spotlight distribution, as compared to the dark spot distribution. Put another way, decreasing the lighting level in the more immediate surroundings of the participants negatively affected their appraisal of the safety-related environmental characteristics. These results thus not only suggest that lighting the immediate environment is important with respect to perceived environmental safety, but also that the informational cues present in the more immediate environment may be more important for the safety perception process than informational cues present in the more remote environment.

Although many extensive theoretical perspectives on how the individual perceptually comes to terms with the environment have been proposed (e.g., Lewin, 1936; Brunswik, 1952; Barker, 1968; Gibson, 1979; Kaplan & Kaplan, 1989), the attention that psychological segmentation of physical space with respect to informational cues has received is relatively sparse. A very broad spatial distinction in informational cues is proposed by Appleton (1975), who discussed the concepts of direct and indirect prospect in the light of his prospect-refuge framework. In much the same way we have characterized prospect in the current thesis, direct prospect refers to the egocentric overview over the situation obtained from one's current vantage point. In contrast, indirect prospect refers to more remote environmental characteristics that are perceived to provide potential opportunities for achieving a good overview. Thus, while the current overview may be partially obstructed, secondary panorama's (e.g., a nearby hilltop) and deflected vistas (e.g., a bend in the road) yield a promise of improved prospect, motivating an individual to pursue these potentially advantageous vantage points.

Where Appleton's distinction remained relatively inexplicit in its definition of particular distances at which indirect prospects turns into direct prospect, Cutting and Vishton (1995) have more exactly specified three distinct spaces; *personal space* (up to 2m), *action space* (2m - 30m), and *vista space* (beyond 30m). These environmental spaces may be thought of as egocentric circular regions that gradually flow into one another. Most interesting for our current discussion is the distinction between action space and vista space. Action space is defined as the area in which public action takes place (e.g., talking, moving about), and is delimited at about 30m by the diminished utility of disparity and motion perspective cues for perceiving structural layout of the environment. In contrast, vista space is defined as the area beyond action space from which comparatively fewer inputs are received for perceiving structural layout, providing a general vista that is relatively unperturbed by motion.

While these specific distance characterizations are primarily defined by the utilization of visual cues for perceiving the structural layout of the environment, the authors importantly distinguish these spaces based on the notion that the perception of space may be related to action. This notion, that the perception of space is related to action, can also be discerned in Hall's (1966) seminal work on proxemics, in which he identified four distinct zones that broadly define the context of social behavior; *intimate distance* (< ~45cm), *personal distance* (~45cm - ~1.2m), *social distance* (~1.2m - ~3.5m), and *public distance* (~3.5m - ~15m). Importantly, Hall does not provide any substantial empirical justification for the specific differentiation of the zones he proposed. Thus, although the work by Hall was highly influential, for example serving as the basis for lighting recommendations such as proposed by Caminada and van Bommel (1980), the question remains whether any conclusions or recommendations based on Hall's zones are justified.

Nonetheless, Hall (1966) defined public distance as the space beyond which social involvement is diminished, serving as a critical distance from which alert subjects can still take evasive or defensive action if threatened. A similar idea is proposed by Goffman (1971), who described the concept of critical distance as the minimal distance required for human adaptive coping behavior. Moreover, Goffman expands on this idea by identifying the *Umwelt* as the egocentric space which entails events that "can and might become a source of immediate concern" (p. 252). In other words, while the critical distance is a relatively short-ranged behavioral threshold for more intensive fight-or-flight type coping behavior, one's attention may be primarily focused on detection and evaluation of informational cues from a substantially larger environmental space. In contrast to the other literature we discussed (e.g., Hall, 1966; Cutting & Vishton, 1995), Goffman (1971) does not specify explicit distances delimiting critical distance or the 'Umwelt'.

Goffman's conceptualization of the *Umwelt* integrates quite well with other accounts of the psychological differentiation of physical space, as both *public distance* and *action space* may be thought of as differentiated from more distal environmental spaces on the basis of the significance of (social) events and behavioral options available within this more immediate environment. We may thus define the *immediate environment* as the space to which we are primarily attuned; from which we extract the most relevant information in order to quickly respond to potential threats and opportunities in our immediate surroundings. The *remote environment* may be defined as the space that extends beyond this immediate environment. The question remains, however, whether these two broad divisions of physical space indeed have distinctive roles in the environmental safety appraisal process.

Research aims

In the current chapter, we aim to extend our understanding of the environmental safety process by exploring whether we are differentially attuned to safety-related information as it is spatially distributed in the environment. One way to investigate how the location of environmental information affects the appraisal process is by manipulating the local availability of information through removing or masking information from stimuli presented to participants. However, merely masking a specific area without masking the remaining areas of a stimulus may lead participants to easily understand the purpose of the experimental manipulation and respond accordingly. The studies presented in the current chapter employ a novel masking paradigm specifically developed to mask different areas within the photographs from our stimulus set (see Chapter 2). To minimize the obviousness of our manipulations, the masking paradigm utilizes a baseline mask complemented with a more dense masking band.[1]

Study 5.1 serves as a pilot study in which we test the effectiveness of the two levels of masking density we employ in the masking paradigm. At the same time, we examine how randomly masking environmental information affects judgments of environmental safety and participants' confidence in their judgment. In Study 5.2, we employ the masking paradigm to locally reduce information, examining whether masking information in the immediate environment more strongly impacts environmental safety appraisals and decision confidence as compared to masking information in the more remote environment. Finally, in Study 5.3, we extend Study 5.2 by improving the methodology, and complementing our own masking paradigm with other mask types, investigating how reducing information in the immediate and remote environment affects participants' accuracy and decision confidence in a rapid dichotomous categorization task (see Chapter 4).

Study 5.1

In this pilot study, we investigated whether, and how, reducing the environmental information available to participants when evaluating a set of photographs affects their judgment of environmental safety and the confidence in their decision. To this end, we compared participants' responses between unmasked and masked stimuli. Adopting the functionalist perspective on environmental perception (see Chapter 1), emphasizing the importance of information processing, we expected that a reduction in information would lead to reduced confidence in judgments about the safety of the environments. Although we

1 We elaborate more on the specifics of our masking paradigm in the 'Materials' sections of the studies presented in the current chapter.

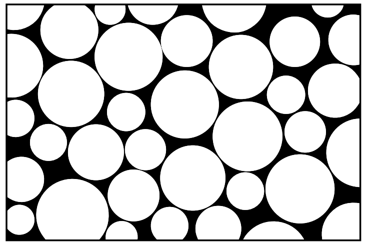
expected that a reduction in information would also affect perceptions of environmental safety (e.g., less information may lead to less accurate appraisals), we had no specific expectations about the direction of the effect. At the same time, the current study tested the relative effectiveness of the two masking densities employed in the masking paradigm of Study 5.2.

Method

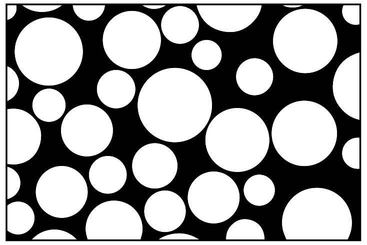
Participants and design. We employed a within-subjects design in which participants evaluated photographs with respect to perceived environmental safety. We applied stimulus masks to the photographs and manipulated the density of the masking. Our independent variable was mask type (i.e., no mask, 20% density mask, 40% density mask; see materials section) and our dependent variables were perceived environmental safety and decision confidence. Our sample comprised 40 participants (23 males and 17 females, M_{age} = 31.4, SD_{age} = 15.37, age range = 19 - 64 years). The participants were registered in the Eindhoven University of Technology's J.F. Schouten participant database and responded to an invitation to participate in our study. Participants required approximately 30 minutes to complete the experiment and received €5,- as compensation for their participation.

Setting and apparatus. Participants were seated behind a desk in one of eight available cubicles. The light was switched on in the cubicles (Ev = 25 lux on the wall at eye height, Eh = 32 lux at desk height). Experiment instructions and stimuli were presented on a 19" color calibrated LCD monitor screen running at 1600 pixels by 1200 pixels resolution and a 60Hz refresh rate. The experiment was presented on the monitor screen using the Macromedia Authorware 7.1 software. Participants responded to the items presented on the monitor screen using the mouse.

Materials and measures. The basic, unmasked stimulus set comprised 84 high resolution photographs of nocturnal urban environments randomly sampled from our set of 100 stimuli (see Chapter 2). We employed a stimulus masking method aimed at randomly reducing the amount of environmental information available to participants. We created two different masks by applying two patterns of randomly positioned circle shaped cut-outs from an opaque dark grey (R=5, G=5, B=5) rectangle, achieving masking densities of 20% and 40% respectively (see *Figure 5.1*). To increase the variety of our masking material, three additional versions of these two mask types were generated that exhibited a different pattern of cutouts while maintaining the overall masking density. In this way, a total of eight masks were created using Adobe Photoshop CS6.



random 20% density mask



random 40% density mask

Figure 5.1. Examples of the 20% density mask type and the 40% density mask type used in Study 5.1.

We created three stimulus sets, each containing 84 experimental stimuli (i.e., photograph + mask type). Each photograph occurred once in each set. We randomly applied one of the three mask types (i.e., no mask, 20% density mask, 40% density mask) to the photographs, such that across the three sets each photograph was paired once with each mask type, and the sets comprised a balanced mix of the three mask types.

We measured perceived environmental safety using three five-point response category 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 Appendix B. We calculated the average of the three items and used these aggregate scores in our analyses (α = .97). We measured decision confidence using one five-point response category format item (i.e., "*How confident are you about your answers to the previous three questions?*"), ranging from (1) "very uncertain" through (3) "neither uncertain / nor confident" to (5) "very confident".

Procedure. Participants were welcomed into the laboratory, instructed to complete an informed consent form, and directed to one of the eight available cubicles. Participants were randomly assigned to one of the three available stimulus sets before the experiment commenced (see materials section), and viewed the total of 84 experimental stimuli from the stimulus set in random order. Participants were instructed to imagine walking alone at night through the depicted environments. For each stimulus, a large version of the stimulus was presented on the monitor screen for five seconds, after which the participant responded to several items presented on the monitor screen. While the participants responded to the questions of our perceived environmental safety and decision confidence measures, a smaller version of the stimulus was present on the monitor screen. After finishing the questions for all the stimuli, the participant responded to three demographic questions about sex, age, and current residence.

Results

Decision confidence. No participants were identified as outliers (i.e., ≥ 3 *SD*s from group average) on the decision confidence measure ($M_{confidence}$ = 4.28, $SD_{confidence}$ = .49, range = 3.44 - 5.00; aggregated over stimuli, stimulus sets, and mask types). Similarly, there were no outliers on the level of the stimuli ($M_{confidence}$ = 4.28, $SD_{confidence}$ = .12, range = 4.03 - 4.53; aggregated over participants, stimulus sets, and mask types).

We used the *mixed* command available in the Stata 13.1 software package to fit a linear mixed-effect model with mask type (i.e., no mask, 20% masking density, and 40% masking density) and stimulus set as fixed effects, participants and stimuli as crossed random effects, and decision confidence as dependent variable. Inspection of the variance components revealed that approximately 40% of the variance in decision confidence could be attributed to the participants. However, only a negligible amount (i.e., < 1%) of the variance could be attributed to the stimuli.

After fitting the model, we used the estimated marginal means from the model in our subsequent analyses (see *Table 5.1*). We compared the marginal means of the unmasked condition and the combined mask conditions (i.e., we tested the overall effect of masking). As expected, we found that decreasing the amount of available environmental information was associated with a decrease in decision confidence (C = -.24, $SD_{contrast}$ = .04, z = -5.60, p < .001). Moreover, as expected, Bonferroni corrected pairwise comparisons revealed that decision confidence was significantly lower for the 40% density mask type as compared to both no masking (C = -.16, $SD_{contrast}$ = .02, z = -6.33, p < .001) and the 20% density mask type (C = -.08, $SD_{contrast}$ = .02, z = -3.36, p = .002). Furthermore, decision confidence in the 20% masking condition was significantly lower as compared to no masking (C = -.07, $SD_{contrast}$ = .02, z = -2.97, p = .009). In line with these findings, we found a modest linear trend, such that increases in masking density across our three mask types were associated with a decrease in decision confidence (C = -.06, $SD_{contrast}$ = .01, z = -6.33, p < .001).

	Decision confidence				Environmental safety			
mask type	M	SE	LLCI	ULCI	M	SE	LLCI	ULCI
no mask	4.36^{a}	.08	4.20	4.51	3.53^{a}	.11	3.32	3.74
20% mask	4.27^{b}	.08	4.12	4.43	3.46^{ab}	.11	3.25	3.67
40% mask	4.20^{c}	.08	4.05	4.35	3.37^{b}	.11	3.16	3.58

Note. Means sharing the same superscript are not significantly different from each other.

Table 5.1. Predicted marginal means (M), standard errors (SE), and lower level (LLCI) and upper level (ULCI) 95% confidence intervals for the measures of decision confidence and perceived environmental safety for each mask type.

Perceived environmental safety. There were no outliers on the level of the participants (M_{safety} = 3.21, SD_{safety} = .63, range = 1.77 - 4.40; aggregated over stimuli, stimulus sets, and mask types). Similarly, no stimuli were identified as outliers on the level of the stimulus (M_{safety} = 3.21, SD_{safety} = .61, range = 1.61 - 4.23; aggregated over participants, stimulus sets, and mask types).

We again fitted a linear mixed-effect model, with mask type (i.e., no mask, 20% density mask, and 40% density mask) and stimulus set as fixed effects, participants and stimuli as crossed random effects, and perceived environmental safety as dependent variable. Inspection of the variance components revealed that approximately ~30% of the variance in perceived environmental safety responses could be attributed to the participants, and another ~30% of the variance could be attributed to the stimuli.

After fitting the model, we used the estimated marginal means from the model in our subsequent analyses (see *Table 5.1*). We compared the estimated marginal means of the umasked condition and the combined mask conditions. We found that a decrease in the amount of available information was associated with a decrease in perceived environmental safety (C = -.23, $SD_{contrast}$ = .07, z = -3.39, p = .001). Bonferroni corrected pairwise comparisons revealed that perceived environmental safety was lower for the 40% density mask type as compared to no masking (C = -.16, $SD_{contrast}$ = .04, z = -4.01, p < .001). No differences were found between the 20% density mask type and no masking (C = -.07, $SD_{contrast}$ = .04, z = -1.86, p = .189), or between the 20% density mask type and 40% density mask type (C = -.09, $SD_{contrast}$ = .04, z = -2.15, p = .094). However, we found a modest linear trend, such that increases in masking density across our three mask types were associated with a decrease in perceived environmental safety (C = -.06, $SD_{contrast}$ = .02, z = -4.01, p < .001).

Discussion

The aim of the current study was to investigate whether reducing the amount of environmental information would lead people to have reduced confidence in their ability to accurately make a decision about the safety of an environment, and, in what way environmental safety appraisals would be affected. We reduced the availability of environmental information by means of randomly masking portions of our stimuli. While the differences between our experimental conditions were relatively small (see *Table 5.1*), contrasting the no-mask condition and the combined masked conditions showed that randomly masking a stimulus was associated with lower evaluations of perceived environmental safety and lower decision confidence. Moreover, we found that increments in masking density (i.e., decreasing the availability of environmental information) across our three levels of mask type were associated with decreases in both perceived environmental safety and decision confidence.

These results thus provide support for our information processing approach to safety perception, suggesting that randomly removing information that may be relevant for the safety appraisal process (a) reduces people's confidence in their decision process, and (b) decreases people's evaluations of the safety of an environment. Furthermore, the results from Study 5.1 show that we may successfully reduce the amount of environmental information available to participants using our masking paradigm.

Study 5.2

Study 5.2 was designed to examine whether we are differentially attuned to safety-related information as it is spatially distributed through the environment. The 20% and 40% density mask types from Study 5.1 were used to create stimulus masks in which we manipulated the masking density over seven different areas within our stimuli. On the basis of our discussion of the relevant theoretical and empirical literature, we expected that sources of environmental information available in the more immediate environment would be more important for the safety appraisal process than sources of environmental information available in the more remote environment. Consequently, we hypothesized that the masking of environmental information in the more immediate environment would impact environmental safety appraisals and decision confidence more strongly as compared to the masking of environmental information in the more remote environment.

Method

Participants and design. We employed a within-subjects design in which participants evaluated photographs with respect to perceived environmental safety. We applied stimulus masks to the photographs and manipulated the density of the masking over different location bands within the stimuli. Our independent variable was mask type (i.e., 7 levels of masking height; see materials section) and our dependent variables were perceived environmental safety and decision confidence. Our sample comprised 38 participants (17 males and 21 females, M_{age} = 25.97, SD_{age} = 11.69, age range = 18 - 61 years). The participants were registered in the Eindhoven University of Technology's J.F. Schouten participant database and responded to an invitation to participate in our study. Participants required approximately 30 minutes to complete the experiment and received €5,- as compensation for their participation.

Setting and apparatus. Participants were seated behind a desk in one of eight available cubicles. The light was switched on in the cubicles (Ev = 25 lux on the wall at eye height, Eh = 32 lux at desk height). Experiment instructions and stimuli were presented on a 19" color calibrated LCD monitor screen running at 1600 pixels by 1200 pixels resolution and a 60Hz refresh rate. The experiment was presented on the monitor screen using the Macromedia Authorware 7.1 software. Participants responded to the items presented on the monitor screen using the mouse.

Materials and measures. Our basic, unmasked stimulus set comprised the same 84 high resolution photographs of nocturnal urban environments that comprised the basic stimulus set of Study 5.1. We used the masking paradigm from Study 5.1, which allowed masking environmental information at different locations within a stimulus. Our base stimulus mask was a dark grey (R=5, G=5, B=5) rectangle with a 20% masking density, covering 100% of the width (i.e., 1024 pixels) and 185% of the height (i.e., 1275 pixels) of the photographs from our stimulus set (see *Figure 5.2*). The full stimulus mask included a band of approximately 280 pixels in height in which the masking density was 40%. The 40% masking band was slightly bent upwards at the extremes to control for perspective in the photographs used as basic stimuli. By gradually shifting the position of the full stimulus mask relative to the photographs, we created seven masking positions (see *Figure 5.3*). To increase the variety of our masking material, three additional versions of the full stimulus mask were generated that exhibited a different pattern of cutouts while maintaining the basic structural layout. In this way, a total of 28 (i.e., 7 masking positions x 4 varieties of the full stimulus mask). All stimulus masks were created using Adobe Photoshop CS6.

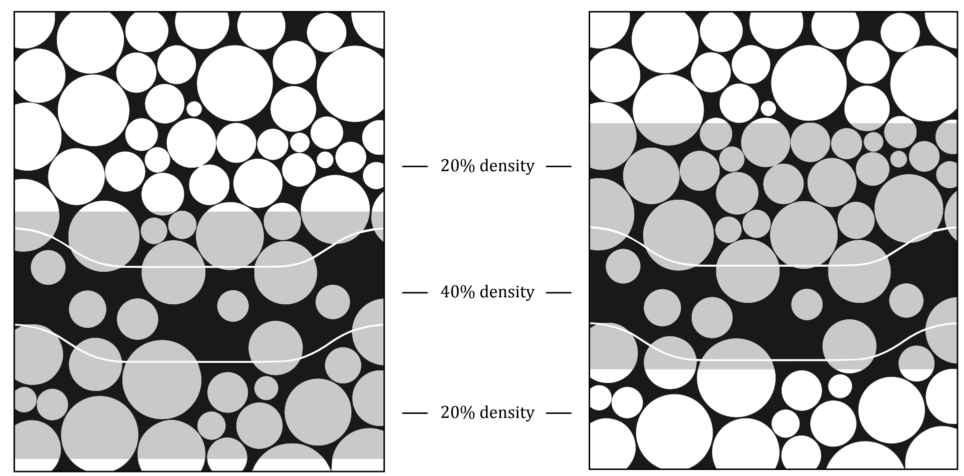


Figure 5.2. Two examples of the full experimental mask paired with a photograph (grey rectangle). In these examples, the 40% density band between the white bars covers different areas of the photograph.

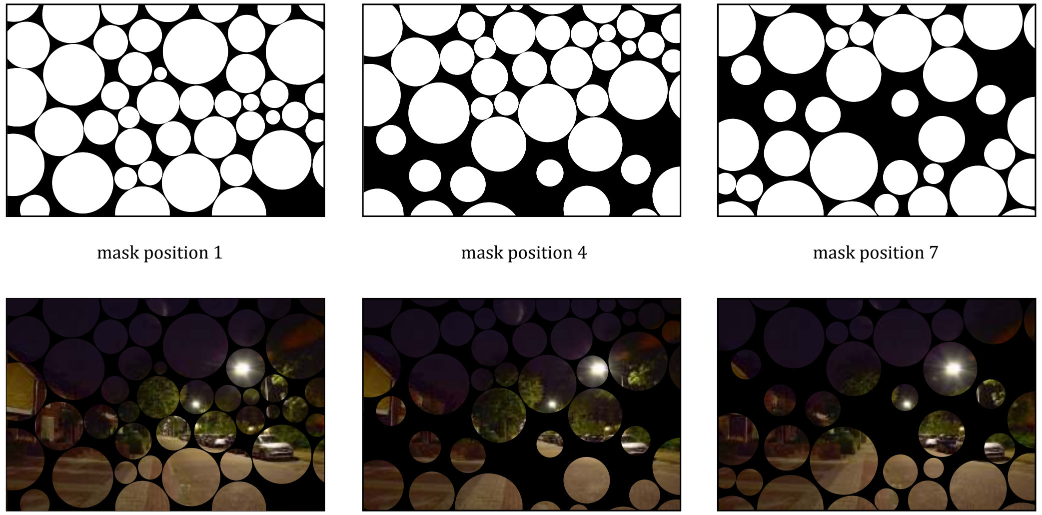


Figure 5.3. Examples of different masking positions used in Study 5.2.

Similarly to Study 5.1, we created seven stimulus sets, each containing 84 experimental stimuli (i.e., photograph + mask). Each photograph occurred once in each set. We randomly applied one of the 28 available masks to the photographs, such that across the seven stimulus sets each photograph was paired once with each masking position, and the sets comprised a balanced mix of the seven masking positions.

We used the same items we used in Study 5.1 to measure perceived environmental safety (α = .98) and decision confidence.

Procedure. The procedure was similar to the procedure followed in Study 5.1. After completing the informed consent form, participants were randomly assigned to one of the seven available stimulus sets (see materials section). Participants then viewed the total of 84 stimuli from their set in random order. Participants were instructed to imagine walking alone at night through the depicted environments. For each stimulus, a large version of the stimulus was presented on the monitor screen for five seconds, after which the participant responded to on-screen questions about the stimulus using the mouse. While the participants responded to the questions of our perceived environmental safety and decision confidence measures, a smaller version of the stimulus was present on the monitor screen. After finishing the questions for all the stimuli, the participant responded to three demographic questions about sex, age, and current residence.

Results

Decision confidence. No participants were identified as outliers (i.e., ≥ 3 *SD*s from group average) on the decision confidence measure ($M_{confidence}$ = 4.18, $SD_{confidence}$ = .56, range = 2.81 - 5.00; aggregated over stimuli, stimulus sets, and mask levels). Similarly, there were no outliers on the level of the stimuli ($M_{confidence}$ = 4.18, $SD_{confidence}$ = .15, range = 3.84 - 4.55; aggregated over participants, stimulus sets, and mask levels).

We used the *mixed* command available in the Stata 13.1 software package to fit a linear mixed-effect model with masking position and stimulus set as fixed effects, participants and stimuli as crossed random effects, and decision confidence as dependent variable. Inspection of the variance components revealed a pattern that was similar to the pattern we found for decision confidence in Study 5.1; approximately 40% of the variance in decision confidence could be attributed to the participants, and a negligible amount (i.e., < 1%) of the variance could be attributed to the stimuli. After fitting the model, we used the estimated marginal means from the model in our subsequent analyses (see *Table 5.2*).

We used Bonferroni corrected pairwise comparisons to test for differences in decision confidence responses between our seven masking positions (1 = lowermost masking position, 7 = uppermost masking position; see *Figure 5.2*). Against our expectations, we found that decision confidence was rated *higher* at masking position 1 as compared to masking position 5 (C = .16, $SD_{contrast}$ = .04, z = 3.51, p = .009), masking position 6 (C = .20, $SD_{contrast}$ = .04, z = 4.34, p < .001), and masking position 7 (C = .17, $SD_{contrast}$ = .04, z = 3.81, p = .003). The other pairwise comparisons indicated that there were no significant differences between all other pairs of masking positions (all zs ≤ 2.97, all ps ≥ .062). In addition, against expectations we found a modest linear trend across all masking positions indicating that as the 40% density band masked higher regions within the stimulus, participants' decision accuracy decreased (C = -.06, $SD_{contrast}$ = .01, z = -5.05, p < .001).

mask position	Decision confidence				Environmental safety			
	M	SE	LLCI	ULCI	M	SE	LLCI	ULCI
1	4.27[a]	.10	4.08	4.45	3.60[a]	.11	3.39	3.82
2	4.20[ab]	.10	4.01	4.39	3.57[a]	.11	3.36	3.79
3	4.17[ab]	.10	3.99	4.36	3.46[ab]	.11	3.25	3.68
4	4.18[ab]	.10	3.99	3.37	3.51[ab]	.11	3.29	3.72
5	4.11[b]	.10	3.92	4.30	3.45[ab]	.11	3.24	3.67
6	4.07[b]	.10	3.88	4.26	3.39[b]	.11	3.18	3.60
7	4.09[b]	.10	3.90	4.28	3.50[ab]	.11	3.28	3.71

Note. Means sharing the same superscript are not significantly different from each other.

Table 5.2. Predicted marginal means (M), standard errors (SE), and lower level (LLCI) and upper level (ULCI) 95% confidence intervals for each masking position in Study 5.2.

Perceived environmental safety. There were no outliers on the level of the participants (M_{safety} = 3.24, SD_{safety} = .60, range = 1.75 - 4.36; aggregated over stimuli, stimulus sets, and mask levels). Similarly, no stimuli were identified as outliers on the level of the stimulus (M_{safety} = 3.24, SD_{safety} = .58, range = 1.63 - 4.28; aggregated over participants, stimulus sets, and mask levels).

We again fitted a linear mixed-effect model with mask location and stimulus set as fixed effects, participants and stimuli as crossed random effects, and perceived environmental safety as dependent variable. Inspection of the variance components revealed that approximately ~30% of the variance in perceived environmental safety responses could be attributed to the participants, and another ~30% of the variance could be attributed to the stimuli. After fitting the model, we used the estimated marginal means from the model in our subsequent analyses (see *Table 5.2*).

The results of the Bonferroni corrected pairwise comparisons for perceived environmental safety revealed a pattern of differences analogous to the pattern of differences for decision confidence. First, against expectations, we found that perceived environmental safety was rated *lower* at masking position 6 as compared to masking position 1 (C = -.21, $SD_{contrast}$ = .06, z = -3.52, p = .009) and masking position 2 (C = -.18, $SD_{contrast}$ = .06, z = -3.02, p = .052). None of the other pairwise comparisons revealed a significant difference (all zs ≤ 2.32, all ps ≥ .274). However, we did find a modest linear trend across all seven masking positions indicating, against our expectation, that as the 40% density band masked higher regions within the stimulus, the evaluation of perceived environmental safety decreased (C = -.05, $SD_{contrast}$ = .02, z = -3.08, p = .002).

Discussion

In the current study we investigated if masking environmental information from specific areas in our stimuli would differentially affect environmental safety appraisals and decision confidence. We expected that masking information in the lowermost masking positions – representing the more immediate environment – would have a bigger impact on safety appraisals and decision confidence than masking information in the uppermost masking positions – representing the more remote environment. On a general level, our results show an opposite pattern, indicating that as masking position increased from the bottom of the stimulus (i.e., masking position 1) towards higher stimulus areas (e.g., masking position 7), participants' evaluations of safety and the confidence in their judgment decreased. Moreover, although the results from the pairwise comparisons revealed only limited differences between the masking positions we defined, we did find linear trends across all masking positions, indicating that increasing the masking position was associated with decreased perceptions

of environmental safety and decisions confidence. These results thus suggest, in contrast to our predictions, that environmental information from the remote environment is more important for achieving confident safety appraisals of the environment.

However, we may identify a number of potential issues with respect to the masking paradigm employed in the current study. First, a concern associated with the masking positions that were associated with significantly more positive judgments of perceived environmental safety and decision confidence (i.e., masking position 1 and masking position 2), is that the total amount of masked information was much lower as compared to the higher masking levels (see *Figure 5.3*). These results may thus merely reflect differences in total available environmental information as opposed to spatially distributed differences in available information, rendering these comparisons invalid for examining the effect of masking environmental information in the immediate and remote environment.

Second, given that there was no precedent for defining the specific regions of interest (i.e., immediate and remote environment) within our stimuli, we opted for an exploratory approach in which we varied the position of the 40% masking band over different areas within our stimuli. Yet, the vertical size of the 40% masking band we defined (~280 pixels in height) may have been too broad to distinguish distinct regions within our stimuli between which people can differentiate. Thus, although people may differentiate between relatively broad regions in real environmental space, the delineation of these regions within two-dimensional photographic depictions of this environmental space might be more challenging.

Third, the representative nature of the environments depicted on the photographs in our stimulus set provided participants with relatively familiar environments. The density of the 40% masking band may not have produced very large deficiencies in the amount of available environmental information, as information could quite easily have been inferred from the remaining 60% of unmasked information still available to the participants. Consequently, the properties of the stimulus masks may have prohibited participants from experiencing large differences in the amount of available environmental information – thus minimizing the differences in perceived environmental safety and decision confidence between our defined masking positions.

Fourth, although the fringes of the 40% masking band were bent upwards to take into account the perspective of the photographs in our stimulus set (see *Figure 5.2*), these design implementations may have insufficiently covered perspective issues. For example, a photograph depicting an alley may be characterized by large occluding objects in the foreground, such as brick walls of adjacent housing blocks, that make up a considerable part of both the lower and upper regions of the stimulus. As a consequence, the mask designed to block information in the more remote environment may have primarily blocked information from the immediate environment (e.g., the brick walls in the foreground) in some of our stimuli, which may have canceled out differences in local information availability.

Finally, even though the aim of the current masking paradigm was to minimize the conspicuousness of removing local information from a stimulus, participants had ample time to view the stimuli and may thus still have noticed that a specific area of the stimuli was masked, adapting their responses accordingly. We attempted to deal with the issues raised here in Study 5.3.

Study 5.3

The aim of the next study was similar to the aim of Study 5.2; to investigate differential attunement to safety-related information as it is spatially distributed through the environment. However, we improved on the design of Study 5.2 in a number of ways. First, to increase the covertness of our masking manipulations, the current study employed the rapid presentation methodology used in Chapter 4 in which participants categorized a set of 30 rapidly presented stimuli. Second, we increased the density of the masking band from 40% to 80%, and divided the area below the average horizon of the photographs in our stimulus set into two non-overlapping regions, reflecting our theoretical distinction between the immediate environment and the more remote environment. In addition to these two mask types based on the masking paradigm employed in the previous two studies, we included two new mask types, previously employed by Larson and Loschky (2009), that represent the distinction between the immediate environment and the remote environment in a different way, and may account more rigorously for perspective issues in our stimuli.

Similar to Study 5.1, the current study included a no mask condition and two random mask types. We expected to replicate the results from Study 5.1, such that randomly masking environmental information would be associated with a decrease in participants' accuracy in the categorization task and their confidence in the categorization decision. More importantly, on top of this general masking effect, we expected that targeted masking of environmental information in the immediate environment would have a stronger impact on participants' response accuracy and decision confidence as compared to the masking of environmental information in the more remote environment, as well as to the random masking of information across the total experimental masking area.

Method

Participants and design. We employed a within-subjects design in which participants rapidly categorized a set of masked stimuli depicting nocturnal urban environments. In each trial of the experiment, participants made a dichotomous judgment about the safety of a randomly presented masked stimulus. Our independent variable was mask type (i.e., no mask, 36% random mask, 31% random mask, low mask, high mask, window mask, and scotoma mask; see materials section) and our dependent variables were participants' categorization accuracy and decision confidence. Our sample comprised 70 participants (49 males and 21 females, M_{age} = 21.5, SD_{age} = 2.91, age range = 17 - 34 years). The participants were registered in the Eindhoven University of Technology's J.F. Schouten participant database and responded to an invitation to participate in our study. Participants required approximately 15 minutes to complete the experiment and received either €5,- or course credit as compensation for their participation.

Setting and apparatus. The current experiment was performed in the same experimental setting and employed the same apparatus as studies 5.1 and 5.2. However, in the current study, we used the E-Prime 2.0 software and the associated serial response box (Psychology Software Tools, Pittsburgh, PA) to present the experiment on the monitor screen and record participants' responses to the stimuli. The serial response box is a dedicated response device capable of recording responses at the millisecond level.

Materials and measures. The basic, unmasked stimulus set comprised the same 30 high resolution photographs of nocturnal urban environments we used in Study 4.2. These 30 photographs consisted of the 15 photographs evaluated as most safe, and the 15 photographs evaluated as most unsafe in Study 2.1. We generated four different experimental masks and two control masks (see *Figure 5.4*), based on an opaque dark-grey mask (R=5, G=5, B=5). The *high mask* and the *low mask* were similar to the circle shaped cut-out masks used in Study 5.2. Both masks consisted of a 20% density base mask and we divided the area below the average horizon (at 43% of the stimulus area as measured from the top of the stimulus) into an upper location band (43% - 71.5%) and a lower location band (71.5% - 100%). Both the upper and the lower location band were slightly bent at the fringes to control for perspective. In the high mask, the upper location band was masked with a density of 80%, and in the low mask, the lower location band was masked with a density of 80%. Both masks had an average masking density of 36%. Four versions of each of these two experimental mask types were generated, each with a different pattern of cut-outs while maintaining the basic structural layout.

We generated two additional experimental masks based on the type of masks typically employed to investigate the role of central and peripheral vision (e.g., van Diepen, Wampers, & d'Ydewalle, 1998; Larson & Loschky, 2009). The *window mask* featured one large circle cut out from the base opaque mask, centered at the average horizon (i.e., at 43% of the stimulus area measured from the top of the stimulus area). The *scotoma mask* was essentially the inverse of the window mask, consisting primarily of a solid dark-grey circle centered at the average horizon. To keep total area masked constant between the window mask and the scotoma mask, the scotoma mask included masked corners in addition to the central mask. In this way, both masks had an average masking density of 31%. These masks extended the circle-shaped cut-out based masks by more rigorously accounting for potential perspective issues and applying a stronger masking intensity (i.e., a 100% blocking of information in defined regions).

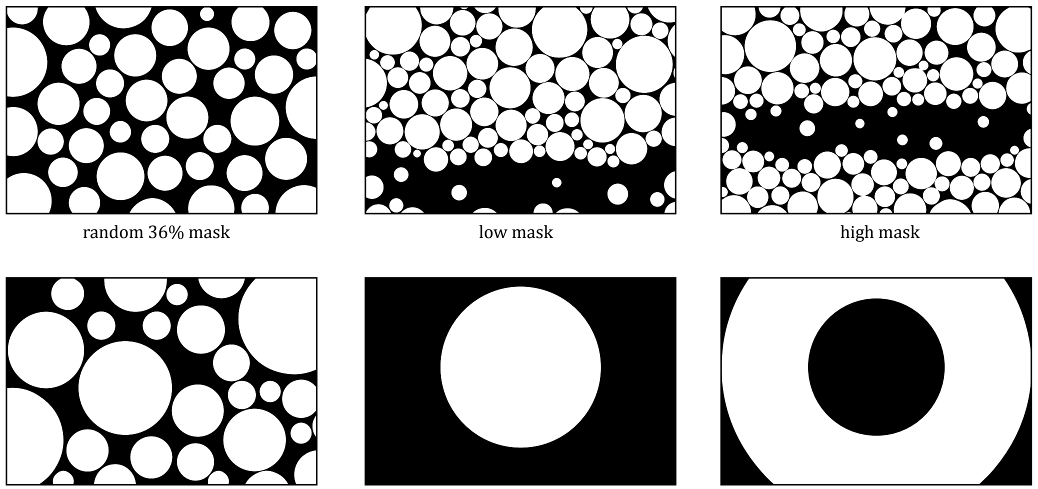


Figure 5.4. Examples of each mask type employed in Study 5.3.

Two control masks were created featuring a random pattern of circle cutouts: one random mask type with a total masking density of 31% and one random mask type with a total masking density of 36%. For each of these two random mask four version were generated. Thus, the total number of stimulus masks generated for this experiment was 18; one window mask, one scotoma mask, four versions of the high mask, four versions of the low mask, and four versions for each of the random masks (see *Figure 5.4*). All stimulus masks were created using Adobe Photoshop CS6.

We measured confidence in the safety judgment using the same five-point response category format item we used in the previous studies reported in the current chapter.

Procedure. After completing an informed consent form, participants were directed to a cubicle where the experiment was presented on the monitor screen using the E-Prime 2.0 software. Following two instruction screens, participants completed 18 practice trials in which they categorized daytime urban environments with respect to environmental safety, before completing the 90 experimental trials. The 90 experimental trials were divided over three experimental blocks each containing all 30 stimuli. Within each experimental block, the stimuli were presented in random order. In each trial, the software randomly paired the stimuli with one of the seven available stimulus mask types (i.e., four experimental masks, two random masks, and no mask). If multiple versions existed for a given stimulus mask type, the software proceeded to randomly select one of the available versions.

Each experimental trial consisted of five phases (see *Figure 5.5*). First, participants were presented with a fixation cross for a random duration between 700ms and 900ms. Importantly, as we were interested in potential differences in the importance of certain areas within a stimulus in a single glance, a fixed position of the fixation cross at the center of the screen may have confounded effects related to differences in location with effects related to differences in foveal and parafoveal vision. Thus, in addition to the random presentation time, the position of the fixation cross was programmed to appear at a random location below the average horizon. Each stimulus was then presented for 50ms, followed by a black screen for 200ms and a visual masking[2] procedure for 133ms. This visual masking procedure consisted of a rapid succession of four greyscale random noise images of varying resolutions presented for 33ms each.

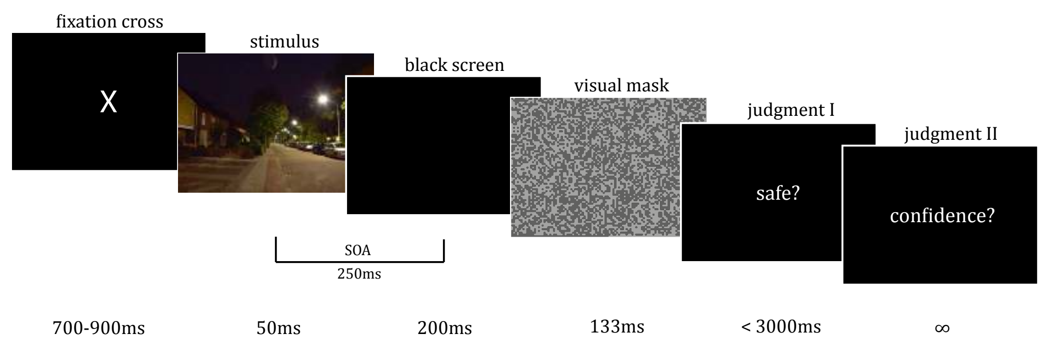


Figure 5.5. The procedure of one experimental trial in Study 5.3.

2 In the current study, we employ both a stimulus mask and a visual mask. While the stimulus mask refers to an overlay that blocks certain information from the photographs in our stimulus sets, the visual masks are implemented to erase visual memory 250ms after the onset of the stimulus.

After the visual masking procedure, participants categorized the depicted environment as either a more safe or a more unsafe environment by pressing the leftmost button or the rightmost button on the stimulus response box respectively. Whether the left or the right button indicated a safe environment was counterbalanced between participants. The participants were allowed a maximum response time of 3000ms before automatically continuing to the next screen. On the final screen presented on the monitor screen, participants used the mouse to indicate how confident they were about their categorization response using the same five-point response category format item used in the previous studies reported in the current chapter. After completing this last part, participants responded to three demographic questions on paper about sex, age, and current residence.

Results

Preliminary analyses. 108 of the 6300 observed experimental trials were removed from the analysis because participants did not respond within the allotted three second response window. One participant was removed because a programming error in the experiment script caused the stimulus presentation times to be 5000ms instead of 50ms. A total of 6102 observed experimental trials were used in the following analyses.

Response accuracy (0 = incorrect, 1 = correct) was computed by comparing the categorization response (i.e., safe or unsafe) with stimulus category (i.e., safe or unsafe) based on the safety evaluations from Study 2.1. Although both the participants from Study 2.1 and the current study were sampled from the J. F. Schouten participant database, there was no overlap in participants between the two samples. There were no outliers (i.e., ≥ 3 *SD*s from group average) on average response accuracy (RA; M_{RA} = .71, SD_{RA} = .08, range = .49 - .87), average decision confidence ($M_{confidence}$ = 3.19, $SD_{confidence}$ = .45, range = 1.84 - 3.92), or average response time (RT; M_{RT} = 962.42ms, SD_{RT} = 246.96ms, range = 418.62ms – 1774.05ms) on the level of the participants (aggregated over stimuli and mask types). We found a modest correlation between average RA and average decision confidence, such that increases in average decision confidence were associated with increases in average RA (r = .27, p = .025). There was no trade-off between average RT and average RA (r = -.04, p = .747), or between average RT and average decision confidence (r = -.09, p = .483).

On the level of the stimuli (aggregated over participants and mask types), there were no outliers on average RA (M_{RA} = .71, SD_{RA} = .12, range = .52 - .90), average decision confidence ($M_{confidence}$ = 3.18, $SD_{confidence}$ = .26, range = 2.72 - 3.84), or average RT (M_{RT} = 958.26ms, SD_{RT} = 73.96ms, range = 771.90ms - 1060.36ms). Similar to the results from the preliminary analyses on the level of the participants, we found a correlation between average RA and average decision confidence (r = .47, p = .009), suggesting that high decision confidence was associated with higher categorization accuracy. In addition, there was a correlation between average RT and average RA (r = -.72, p < .001), and between average RT and average decision confidence (r = -.81, p < .001), which indicate that some stimuli were relatively more difficult to categorize, resulting in longer response latencies, reduced response accuracy, and reduced decision confidence.

In contrast to the results from the studies presented in Chapter 4, in which we applied a similar dichotomous categorization task that drew on an identical stimulus set, we did not find a tendency for participants to categorize the stimuli as safe; approximately 50% of all 6102 categorizations were categorized as safe. However, when we considered the categorizations for the no mask condition (i.e., the condition that is comparable to the stimuli used in Chapter 4) separately, we did find a comparable tendency to categorize the stimuli as safe; approximately 65% of 876 categorizations were categorized as safe.

Decision confidence. We used the *mixed* command to fit a linear mixed-effect model with mask type as fixed effect, participants and stimuli as crossed random effects, and decision confidence as dependent variable (see *Table 5.3* for the marginal means estimated from the model).

As expected, we replicated the results from Study 5.1, such that randomly masking environmental information was associated with lower decision confidence as compared to no masking (C = -1.07, $SE_{contrast}$ = .08, z = -13.02, p < .001). However, against our expectations, we found that the average decision confidence associated with the high mask (i.e., masking the remote environment) was lower than the average decision confidence associated with the low mask (i.e., masking the immediate environment; C = -.30, $SE_{contrast}$ = .05, z = -6.31, p < .001) and the random 36% mask (C = .28, $SE_{contrast}$ = .05, z = 5.96, p < .001). In addition, we found no difference in average decision confidence between the low mask and the random 36% mask (C = -.02, $SE_{contrast}$ = .05, z = -.37, p = .709).

mask type	M	SE	LLCI	ULCI
no mask	3.67	.08	3.52	3.82
random 31%	3.18	.08	3.03	3.33
random 36%	3.10	.08	2.95	3.25
scotoma mask	3.32	.08	3.17	3.47
window mask	3.09	.08	2.94	3.24
high mask	2.81	.08	2.66	2.96
low mask	3.11	.08	2.96	3.27

Table 5.3. Predicted marginal means (M), standard errors (SE), and lower level (LLCI) and upper level (ULCI) 95% confidence intervals for the decision confidence measure by mask type employed in Study 5.3.

In contrast, the average decision confidence associated with the window mask (i.e., masking the immediate environment) was significantly lower than the average decision confidence associated with the scotoma mask (i.e., masking the remote environment; $C = -.23$, $SE_{contrast} = .05$, $z = -4.89$, $p < .001$) and the random 31% mask ($C = -.14$, $SE_{contrast} = .05$, $z = -3.00$, $p = .003$). In addition there was no significant difference in average decision confidence between the scotoma mask and the random 31% mask ($C = .09$, $SE_{contrast} = .05$, $z = 1.90$, $p = .057$).

Response accuracy. We used the *meqrlogit* command to fit a logistic linear mixed-effect model with mask type as fixed effect, participants and stimuli as crossed random effects, and response accuracy (RA; 0 = incorrect, 1 = correct) as binary dependent variable. After fitting the model, we calculated the marginal means (see *Table 5.4*) used for testing specific contrast. The pattern of results for the response accuracy contrasts was identical to the pattern of results for the decision confidence contrasts outlined above.

mask type	M	SE	LLCI	ULCI
no mask	.79	.02	.74	.84
random 31%	.75	.03	.70	.81
random 36%	.74	.03	.69	.80
window mask	.70	.03	.64	.76
scotoma mask	.76	.03	.71	.81
high mask	.64	.03	.58	.70
low mask	.74	.03	.69	.80

Table 5.4. Predicted marginal means (M), standard errors (SE), and lower level (LLCI) and upper level (ULCI) 95% confidence intervals for the response accuracy measure by mask type employed in Study 5.3.

As expected, we found that the random masking of environmental information was associated with a decrease in average RA as compared to the no mask condition ($C = -.47$, $SE_{contrast} = .20$, $z = -2.35$, $p = .019$), replicating the basic finding from Study 5.1. Against our expectations, we found that the average RA associated with the high mask (i.e., masking the remote environment) was lower than the average RA associated with the low mask (i.e., masking the immediate environment; $C = -.49$, $SE_{contrast} = .11$, $z = -4.46$, $p < .001$) and random masking (i.e., the random 36% mask; $C = -.48$, $SE_{contrast} = .11$, $z = -4.40$, $p < .001$). As expected, we found no difference in average RA between the low mask and the random 36% mask ($C = -.01$, $SE_{contrast} = .11$, $z = -.08$, $p = .938$).

We found an opposite accuracy pattern with respect to the window and scotoma mask types. While the average RA associated with masking the immediate environment (i.e., the window mask) was significantly lower than the average RA associated with masking the remote environment (i.e., the scotoma mask; $C = -.32$, $SE_{contrast} = .11$, $z = -2.88$, $p = .004$) and the average RA associated with the random 31% mask ($C = -.28$, $SE_{contrast} = .11$, $z = -2.48$, $p = .013$), we found no difference in average RA between the scotoma mask and the random 31% mask ($C = -.04$, $SE_{contrast} = .11$, $z = -.39$, $p = .699$).

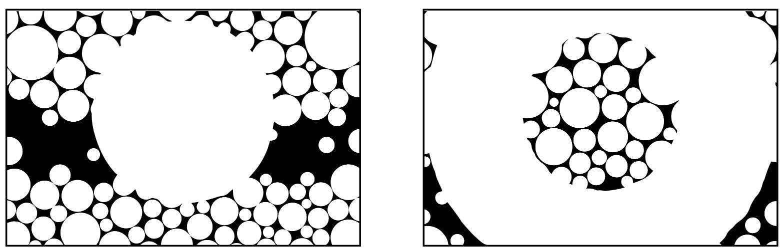
Discussion

In the current study we have employed a rapid categorization paradigm (see Chapter 4) to further investigate how masking environmental information in the immediate and remote environment affects the safety appraisals process. In line with the results from Study 5.1, we found that randomly masking environmental information was associated with decreased categorization accuracy and decision confidence. Moreover, we found that masking environmental information in the remote environment using a high mask was associated with decreased categorization accuracy and decision confidence as compared to masking environmental information in the immediate environment using a low mask or random masking of information. Against our expectations, these results thus corroborate the general trend demonstrated in Study 5.2, indicating that environmental information in the remote environment was more important for the safety appraisal process than environmental information in the immediate environment.

However, while we replicated the findings that masking the remote environment has a stronger influence on the appraisal of environmental safety using the circle-shaped cutout masking paradigm, our findings indicate an opposite pattern of results for the scotoma mask/window mask combination. For these mask types, we found that masking environmental information in the immediate environment (i.e., the window mask) was associated with decreased categorization accuracy and decision confidence as compared to masking environmental information in the remote environment (i.e., the scotoma mask) and the random masking of information. Hence, these results seem to provide evidence for our hypothesis that information from the immediate environment is more important for the safety appraisal process than information from the remote environment.

At first glance, the response patterns associated with the two mask type combinations thus seem contradictory, particularly when we interpret the results in terms of our pre-defined operationalization of the immediate and remote environment (e.g., the scotoma mask targets the remote environment, or the low mask targets the immediate environment). However, it may be informative to temporally abandon this operationalization, and examine the commonalities of the two effective mask types, which in fact demonstrated an effect beyond random masking (i.e., the high mask and the window mask), and the two ineffective masks that did not demonstrate an effect beyond random masking (i.e., the low mask and the scotoma mask). To this end, we created a composite mask for both the effective and the ineffective mask types (see *Figure 5.6*).

Visual inspection of the composite masks presented in *Figure 5.6* reveals that the masked (i.e., black) areas that are shared by both effective mask types are situated at approximately the height of the high mask, extending from the edges of the stimulus inwards toward the beginning of the window cutout. Moreover, although we cannot identify specific masked regions that are shared by the ineffective mask types, the commonalities in *unmasked* (i.e., white) stimulus area for the ineffective mask types correspond largely to the commonalities in *masked* stimulus area we identified for the effective mask types. The examples shown in *Figure 5.7*, applying the inverse of the effective mask (i.e., *Figure 5.6a*) to photograph from our stimulus set, demonstrate what information is typically blocked by the effective masks. Inspection of these examples reveals that the information that is typically masked by the effective masks is situated in the horizontal peripheries of the environments, no more than a few meters ahead.



a b

Figure 5.6. (a) The area covered by both effective masks (i.e., the high mask and the window mask). (b) The area covered by both ineffective masks (i.e., the low mask and the scotoma mask).

Thus, although we may not be able to pinpoint exactly what we are masking, our results do identify areas that seem to impact the safety appraisal process more strongly as compared to other areas within the stimuli. While such a conclusion agrees with our general notion that environmental space is psychologically differentiated and that people process safety-related informational cues accordingly, it remains unclear what the current results imply for the more specific hypotheses about the impact of environmental information from the more immediate and the more remote environment. We return to this issue in the general discussion.

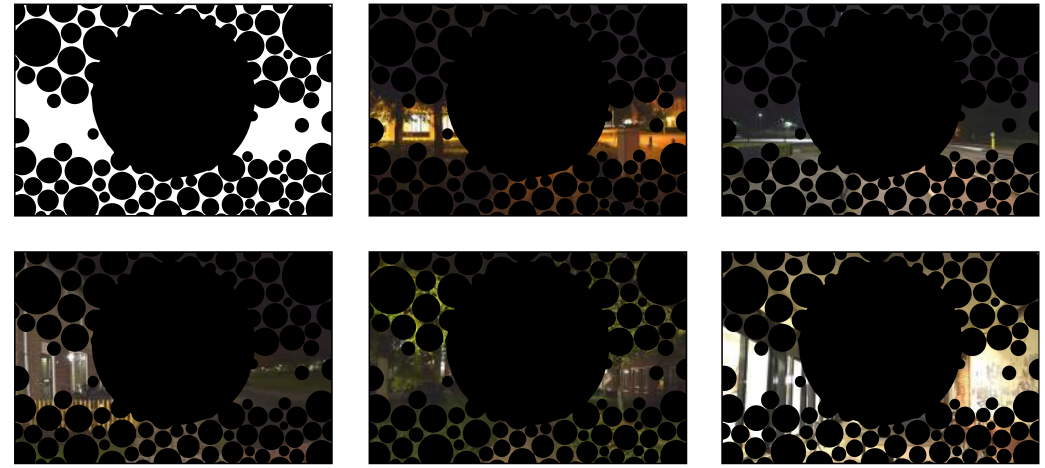


Figure 5.7. Examples showing the areas typically blocked by the effective masks. Top left image is the inverse of the combined effective mask shown in Figure 5.6a.

General discussion

The aim of the current set of studies was to broaden our understanding of the environmental safety appraisal process by exploring (a) whether the masking of informational cues from the environment affects appraisals of environmental safety and the confidence in the ability to achieve accurate safety judgments, and (b) whether we are differentially attuned to safety-related information as it is spatially distributed through the environment. For this purpose, we employed a newly developed masking paradigm based on patterns of circle-shaped cutouts. This masking paradigm allowed us to mask environmental information without resorting to rigorously masking broad areas, and to systematically mask information more unobtrusively. We will discuss the results with respect to the general and spatially differentiated effects of masking environmental information in more depth in the following paragraphs.

Masking environmental information

On a broad level, we examined how randomly masking environmental information affects the environmental safety appraisal process. Given the theoretically postulated importance of safety-related informational cues from the environment, the impairment of obtaining a sufficient amount of information from the environment was expected to negatively impact people's confidence in achieving accurate appraisals of environmental safety. More specifically, we expected that randomly masking environmental information would be associated with diminished confidence in the ability to achieve accurate environmental appraisals. Furthermore, although we expected that a reduction in information would also affect perceptions of environmental safety (e.g., less information may lead to less accurate appraisals), we had no specific expectations about the direction of the effect.

Our results corroborate the idea that reducing environmental information negatively impacts the safety appraisal process. In Study 5.1, we found that randomly masking environmental information was associated with more negative evaluations of perceived environmental safety and with decreased decision confidence. Moreover, we found that the increments in masking density across the three mask types (i.e., no mask, 20% density mask, and 40% density mask) were associated with decreases in both perceived environmental safety and decision confidence. We replicated these results in Study 5.3, in which randomly masking environmental information, as compared to no masking of information, was associated with a decrease in average response accuracy and decision confidence. In addition, the results from Study 5.3 showed that randomly masking information was associated with significantly longer response latencies as compared to no masking. Thus, these results suggest that removing informational cues from the environment reduces the efficacy of the safety appraisal process, providing support for the idea that information processing is key for achieving accurate environmental appraisals.

However, in addition to providing support for the information-processing framework, the combination of our measures of perceived environmental safety (i.e., using the five-point response category format measure as well as the dichotomous categorization task) and decision confidence, allows us to consider the safety appraisal process in some more depth. In both Study 5.1 and Study 5.2, participants reported very high levels of confidence in their evaluations of masked stimuli with respect to environmental safety. What is more, even though the rapid presentation time of the masked stimuli significantly impaired viewing conditions in Study 5.3, participants still reported neutral to positive levels of confidence in the categorization task. These results suggest that participants generally believe that they are capable of achieving accurate appraisals of environmental safety for the different sets of stimuli used in our studies.

Yet, we also found that levels of decision confidence, similarly to appraisals of environmental safety, were negatively impacted by the masking of environmental information across all three studies. In fact, the pattern of results associated with decision confidence closely followed the pattern of results observed for participants' evaluations of environmental safety and categorization accuracy. Additionally, we found that reported levels of decision confidence were correlated with both environmental safety appraisals and response accuracy in the rapid categorization task. Although these results suggest that decision confidence may be an important aspect of the safety appraisal process, the experimental design of our studies

does not allow us to further specify the relationship in terms of the underlying causal chains.

A final note concerns participants' overall high accuracy in the rapid categorization task with 50ms presentation time and 250ms stimulus onset asynchrony we employed in Study 5.3. Similar to the studies presented in Chapter 4, participants again demonstrated high categorization accuracy, providing further support for the notion that people are able to rapidly achieve quite accurate appraisals of environmental safety. Importantly, the lower level 95% confidence intervals for response accuracy associated with any level of masking was still above chance level (i.e., all LLCIs ≥ .58; see *Table 5.4*). These findings suggest that even when people are not provided with all available environmental information, achieving accurate environmental appraisals is not exceedingly impaired.

Masking localized information

In our introduction of the current chapter, we developed the idea of a spatial differentiation of environmental space (i.e., a differentiation in an immediate environment and a more remote environment), and predicted that masking environmental information in the immediate environment would affect appraisals of environmental safety and decision confidence more strongly as compared to masking information in the more remote environment. To examine the effect of masking information from different areas within our stimuli, we varied the position of our stimulus mask, consisting of a 20% density base mask complemented with a 40% density masking band, relative to our stimuli to create seven levels of masking position (see *Figure 5.2* and *Figure 5.3*). In contrast to what we expected, we found a linear trend that indicated that increasing the position of the more densely masked band from the bottom of the stimulus (i.e., the immediate environment) toward the position around the average horizon (i.e., the remote environment) was associated with more negative appraisals of environmental safety and a lower decision confidence. In addition, despite several improvements to our masking paradigm in Study 5.3, we again found that the high mask (targeting the more remote environment) was associated with decreased perceptions of environmental safety and with decreased decision confidence as compared to the low mask (targeting the immediate environment). While the finding that masking information in the remote environment is more important than masking information in the more immediate environment is in conflict with our prior expectations, our results generally support the underlying idea that environmental information from certain regions within an environment may indeed be more important for the safety appraisal process than information from other regions within the environment.

Nevertheless, in Study 5.3 we also included two additional mask types targeting the immediate environment (i.e., window mask) and the remote environment (i.e., scotoma mask), and found the exact opposite pattern, suggesting that information from the immediate environment is more important for the safety appraisal process than information from the remote environment. This seemingly contradictory pattern of results with respect to different mask type combinations (i.e., low mask vs high mask, and window mask vs scotoma mask) may have primarily been an artifact of our operationalization of the differentiation of environmental space (see Limitations section). Yet, considering only the areas covered by the effective masks, we identified two areas in the horizontal periphery of the stimuli (see *Figure 5.6a*) that seem to impact the safety appraisal process more strongly as compared to other areas. Thus, although we may not be able to pinpoint exactly what we are masking, our results do provide evidence for the notion that the processing of environmental information is adapted to psychological differentiation of environmental space.

Limitations

In addition to the limitations we discussed in the previous paragraphs, we may identify three more general limitations of the studies presented in the current chapter. First, the question remains to what extent the apparent differentiation of environmental space within our stimuli is representative for spatial differentiation in the real world. One of the reasons underlying the complexity of the operationalization of the immediate and remote environment in the experimental designs of the studies presented in the current chapter, is that the proposed spatial differentiation is based on abstract theoretical considerations that do not translate well into more straight-forward physical properties of an environment. For example, Hall's *public distance* refers to any distance beyond the critical distance of 3.5m (Hall, 1966), and Goffman (1971) only concedes that the immediate environment should not comprise more than a few meters. However, even if we are provided with more well-defined distances, such as in the case of Cutting and Vishton (1995), who defined the boundaries of *action space* at approximately 30m, we are faced with the issue of correctly representing such a three-dimensional distance across our set of two-dimensional depictions of real-world environments. Did our effective masks in Study 5.3 truly mask information that exceeded this 30m boundary distance? Or did these masks only cover somewhat more remote regions within 30m distance?

Second, the complexity of operationalizing differentiations in environmental space may be further compounded by acknowledging the dynamism of environmental space perception as proposed by Goffman. While our studies employ static depictions of environments as well as static operationalizations of spatial differentiation of environmental space (i.e., the masks statically mask a specific region within the stimulus), Goffman thinks of spatially differentiated parts of environmental space as dynamically contracting and expanding fields

of information. Thus, from such a perspective, any kind of static operationalization appears to be destined to result in an inaccurate representation of spatial differentiations. Such inaccurate representations may be mitigated or avoided using appropriate masking methods in more immersive research settings. For example, although there is a risk of tripping hazards becoming disproportionally salient, future studies may employ glasses specially designed to mask environmental information in a real-world setting. A more feasible option may be the employment of immersive 3D virtual reality settings that are more true to nature as compared to viewing 2D images on a monitor screen. In these type of studies, researchers can methodically control the availability of environmental information through the design of the virtual setting, avoiding the problems associated with investigating depth-dependent perceptions of environmental space using 2D images. In sum, to validate the preliminary conclusions drawn from the current set of studies, future research may focus on developing more ecologically justified masking paradigms as well as methodologies for investigating the masking/removing of environmental information in ecological settings.

Third, the stimulus set used in our studies is fully comprised of photographs of nocturnal urban environments. We may thus extend our concern with regard to the dynamism of environmental space perception to raise a potential issue that may be associated with the relative homogeneity of our stimulus set. For example, given that there are more opportunities for potential offenders to hide in the dark, the environmental space towards which one is attentive to potential threats and opportunities may be larger as compared to the environmental space towards one is attentive to such events during the day. We may expect similar differences in the relative boundaries of differentiated environmental space between urban environments and more rural or natural environments. Future research may thus focus on extending our findings beyond our relatively limited set of nocturnal urban environments.

Conclusion

The current set of studies do provide compelling support for our information-processing account of environmental safety perceptions, showing that the impairment of information-processing by masking environmental information is associated with more negative appraisals of environmental safety and lower levels of confidence in the decision process. Furthermore, while we may not yet be able to specify the results according to our theoretical distinction of environmental space in a more immediate environment and a more remote environment, our results clearly demonstrate that people do indeed differentiate environmental space, and that the acquirement of safety-relevant information is distributed accordingly.

Chapter 6

General discussion

6

Feelings of insecurity in public space are associated with detrimental effects on, for example, social behavioral patterns (e.g., Warr; 1985; 1990; Keane, 1998) and physical as well as mental well-being (e.g., Stafford et al., 2007; Jackson & Stafford, 2009; Moons & Shields, 2015). Despite relatively mixed findings in the literature, the implementation or improvement of public lighting remains one of the most often employed strategies for dealing with concerns about public experiences of safety (e.g., Cozens et al., 2005). In the light of new questions raised by societal pressures and the emergence of novel ways in which we may illuminate public space, and the potential insuffiency of current lighting recommendations – based on more conventional public lighting systems – to adequately deal with these questions, we identified a need to better understand how lighting affects our immediate sense of safety.

Although we characterized a variety of factors that have been shown to impact the perception of safety (e.g., Skogan & Maxfield, 1981; Skogan, 1986; Warr, 1990; Heath & Gilbert, 1996; Brownlow, 2005; Foster et al., 2010; Fisher & May, 2007; Boomsma & Steg, 2014), the aim of the studies presented in the current thesis was to develop a theoretical understanding of the process through which appraisals of physical characteristics of the proximate environment – including lighting – affect the immediate perception of the safety of an environment. To this end, we adopted a functionalist approach to environmental perception, emphasizing the importance of selecting and weighing information from the immediate environment to achieve accurate appraisals of certain environmental qualities (e.g., Brunswik, 1952; Kaplan & Kaplan, 1989). More specifically, we focused on the proximate cue framework that, based on Appleton's (1975) prospect-refuge theory, identifies three potentially relevant environmental characteristics that may influence the appraisal of environmental safety (e.g., Fisher & Nasar, 1992; Nasar et al., 1993; Loewen et al., 1993; Nasar & Jones, 1997): *prospect* (the extent to which the environment offers an overview over a scene), *concealment* (the environmental affordance of hiding places for potential offenders), and *entrapment* (the extent to which environmental characteristics impede escape in case of an emergency).

In the studies presented in the current thesis, we have examined the validity of the proximate cues approach to understanding environmental safety appraisals, utilizing a large range of stimuli depicting ordinary nocturnal urban environments, and investigated the influence of, and interaction between, environmental (i.e., characteristics of the proximate environment – including lighting) and individual (distal) factors in the safety appraisal process (Chapter 2 and Chapter 3). Furthermore, within the context of the safety perception literature, the studies reported in Chapter 4 and Chapter 5 employed novel research paradigms aimed at gaining a deeper understanding of the environmental safety appraisal process. In the following sections, we will discuss the main findings from our studies in the light of the broader theoretical framework presented in Chapter 1, raise some potential methodological issues, offer recommendations for future work, and consider the potential theoretical and practical implications of the current findings.

Environmental determinants of safety in the proximate environment

Utilizing a large set of photographs depicting nocturnal urban environments that broadly represent the environments people may encounter on a daily basis, our findings validate previous findings from the literature, highlighting the importance of proximate environmental cues in the environmental safety appraisal process (e.g., Fisher & Nasar, 1992; Nasar et al., 1993; Nasar & Jones, 1997; Blöbaum & Hunecke, 2005; Boomsma & Steg, 2014; Haans & de Kort, 2012). We found a high correlation between participants' appraisals of safety-related environmental characteristics (i.e., prospect, concealment, and entrapment) and independent appraisals of the safety of these environments, and repeatedly demonstrated that appraisals of environmental safety may be predicted from appraisals of the safety-related environmental characteristics – with appraisals of prospect, concealment, and entrapment robustly accounting for approximately 75% of the variance in environmental safety appraisals across our set of stimuli (see Chapter 2 and Chapter 3). Notably, although the environmental qualities of interest were evaluated by independent judges, we found relatively high agreement in appraisals of environmental safety and safety-related environmental characteristics among participants, both within and between individual studies. These latter findings suggest that physical characteristics of the environment are more important in the safety appraisals process than characteristics of the individual evaluating an environment, a point we return to in the section on the influence of the individual.

With regard to the relative contributions of the three safety-related environmental characteristics, our results are in line with previous findings demonstrating the relative primacy of appraisals of entrapment (i.e., the extent to which an environment possesses characteristics that impede escape from a dangerous situation) in the safety appraisal process (e.g., Blöbaum & Hunecke, 2005; Boomsma & Steg, 2014). The contributions of appraisals of prospect and, to an even larger extent, concealment, are much less prominent in our studies. While the results from Study 2.1, in which we aggregated over participants and analyzed average appraisals on the level of our stimuli, did reveal appraisals of prospect as a significant predictor of environmental safety appraisals, we found that only very minimal predictive power could be attributed to appraisals of prospect in the studies presented in Chapter 3 – employing a more elaborate statistical model to account for variance stemming from both individual and environmental characteristics. With regard to the contribution of appraisals of concealment, the results of our different studies, utilizing both analyses on the level of the stimulus as well as hierarchical analyses, yielded very limited support for a significant role of appraisals of concealment in the environmental safety appraisal process.

A potential explanation for the lack of predictive power of appraisals of prospect and concealment across our studies may be that most of the studies that report (larger) effects of these environmental appraisals are performed in situ, as opposed to viewing stimuli depicting environments on a monitor screen. While the choice of our methodology was justified by our aim to extend the range of environments considered in the safety-related environmental characteristics domain (see Chapter 1), and by research showing that people respond similarly to virtual environments as they would to real environments (e.g., Stamps, 1993; 2010), we cannot rule out the possibility that the extent to which environments offer an overview over the situation or places to hide for a potential offender becomes more salient, and thus more important, when one finds oneself in a real environment at night. Future research aimed at investigating the role of the safety-related environmental characteristics in a wider range of representative real-world environments may provide a test of the robustness of our findings outside the laboratory.

Whereas our results thus corroborate previous findings by demonstrating that appraisals of safety-related environmental characteristics are important for inferring the safety of an environment, the evidence for the individual impact of appraisals of prospect, concealment, and entrapment provided by our studies is less clear-cut. One difficulty with regard to the straighforward interpretation of the individual contributions of our predictors were the high correlations we found between our measures of prospect, concealment, and entrapment. In Chapter 2, we have emphasized that regression weights produced by multiple regression analysis fail to appropriately partition variance to model predictors when there are issues of multicollinearity (e.g., Darlington, 1968), and employed statistical tools to provide a better assessment of individual contributions of correlated predictors, revealing comparable results with respect to the *relative* importance of the safety-related environmental characteristics as compared to the biased regression weights.

Aside from these methodological considerations, the high correlations between our independent measures of prospect, concealment, and, to a lesser extent, entrapment also bear some potential theoretical implications worth discussing. Given the wide range of environments that comprised our stimulus set, these correlations suggest that appraisals of these environmental characteristics tend to covary in the natural world. While it may be true that this is entirely due to recurring configurations of objective properties of the environments under consideration, it may also be that appraisals of safety-related environmental characteristics share a common mechanism and reflect, at least partially,

more fundamental psychological appraisals of our environment. Importantly, these naturally occurring corvariations are frequently overlooked in the factorial designs commonly employed to investigate the role of the safety-related environmental characteristics (e.g., through the artificial untying of correlated variables). In the light of the current findings, an important question that may be raised is why these safety-related appraisals of the environment are so highly correlated.

Mechanisms underlying appraisals of environmental characteristics

We may identify a number of potential mechanisms underlying the high covariation between appraisals of the safety-related environmental characteristics (i.e., prospect, concealment, and entrapment). For example, from a functionalist perspective that stresses information processing as an adaptive mechanism for effective functioning in the environment, the assessment of the amount of unconstrained visual information an environment offers (i.e., appraisals of prospect and concealment), may well be associated with the ability to successfully predict events that are likely to occur in our immediate environment. In turn, predictable environments may increase the sense of informational control (e.g., Averill, 1973) we have over our surroundings, and, as a result, increase our sense of safety. Interestingly, the environmental factors identified in the preference matrix model (Kaplan & Kaplan, 1989) may also be subject to these more fundamental mechanisms of environmental perception, as appraisals of environmental predictability may well underlie the prominence of environmental characteristics that facilitate understanding (i.e., *coherence* and *legibility*) and hold the promise of further information (i.e., *mystery*). The visual richness of an environment (i.e., *complexity*) may both provide additional informational cues that enhance the predictability of the environment as well as overwhelm an observer with information if the visual richness increases beyond a certain threshold level – an interpretation that is in line with the inverted U-shape effect of mystery on environmental preferences commonly demonstrated in the literature (e.g., Kaplan & Kaplan, 1989). As this example makes clear, investigating the more fundamental psychological mechanisms through which environmental characteristics affect our perception of the environment may provide a more comprehensive framework from which we may interpret different approaches to understanding immediate environmental determinants of perceived environmental safety.

However, the extent to which an environment offers informational control may not be the sole fundamental appraisal of the environment underlying the significance of the various environmental characteristics associated with perceptions of safety. Rather, given that appraisals of entrapment consistently demonstrated the largest predictive potential across our studies, and Kaplan and Kaplan (1989) conceding that, amongst others, the experience of competence characterizes effective functioning in the environment, the assessment of informational control may additionally be complemented by an assessment of the amount of behavioral options available in case of an unforeseen emergency. Viewed from this perspective, the finding that appraisals of entrapment have by far the largest influence on perceptions of environmental safety suggests that appraisals of the behavioral control an individual has over the environmental context are more important than appraisals of informational control (i.e., environmental predictability). To understand more thoroughly how the two main approaches to understanding perceptions of safety from appraisals of environmental characteristics in the immediate environment (i.e., based on Appleton's prospect-refuge model, or based on Kaplan and Kaplan's preference-matrix model) may be reconciled with one another, more research should be appropriated to investigate the mechanisms underlying the prominence of appraisals of safety-related environmental characteristics in the safety appraisal process – of which the informational and behavioral control account is but one example.

The role of lighting

Public lighting is commonly associated with positive effects on the experience of safety in public space (e.g., Welsh & Farrington, 2008; Fotios et al., 2014; Lorenc et al., 2013). Research applying the proximate cue framework has identified two potential ways in which lighting, considered as an environmental feature in the proximate environment, may affect perceptions of environmental safety. A first major perspective interprets lighting as a distinct informational cue in the environment (e.g., Loewen et al., 1993; Blöbaum & Hunecke, 2005). While this interpretation does not rule out potential interactions between lighting and other safety-related environmental appraisals (e.g., prospect), the mere presence of lighting is expected to have a direct effect on the perception of environmental safety that is independent from other safety-related informational cues. A second approach, that depends less on the assumption of factorial independence, emphasizes that the effects of lighting on safety appraisals are mostly indirect, and may be mediated by the influence of lighting on appraisals of other safety-related environmental characteristics (e.g., Haans & de Kort, 2012).

In Chapter 2, we presented a number of studies in which we examined these approaches to understanding how lighting may influence perceptions of environmental safety, by exploring how appraisals of the quality of the lighting of an environment are related to appraisals of environmental safety as well as to appraisals of prospect, concealment, and entrapment (see *Figure 2.1*). The results from Study 2.2 demonstrated that appraisals of the

quality of the lighting accounted for a significant share of the variation observed in reported appraisals of environmental safety. These results conceptually replicate previous findings from the literature showing that appraisals of lighting affect the perception of safety in an environment (e.g., Loewen et al., 1993; Blöbaum & Hunecke, 2005). However, including these lighting appraisals as an additional predictor in our regression model, predicting perceived environmental safety from appraisals of prospect, concealment, and entrapment, revealed that appraisals of the quality of the lighting did not predict environmental safety appraisals beyond appraisals of the safety-related environmental characteristics. Moreover, when we accounted for the effect of the appraisals of the quality of the lighting on appraisals of prospect, concealment, and entrapment, the effect of lighting on perceived safety was no longer significant.

While the results from Study 2.2 corroborate the findings presented by Haans and de Kort (2012), showing that the effect of a lighting manipulation on perceived safety is mediated by appraisals of safety-related environmental characteristics, our results 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 on perceived safety. This is most likely a consequence of the lack of a direct effect of concealment on perceived environmental safety we observed in Study 2.1. Second, while Haans and de Kort report a small direct effect of lighting on perceived safety after accounting for the influence of the mediating variables (i.e., partial mediation), our results indicate that appraisals of lighting do not affect perceived environmental safety beyond the effect of the safety-related environmental characteristics (i.e., full mediation). A possible explanation for this discrepancy is that where Study 2.2 deals with appraisals of the quality of the lighting in the environments depicted by the photographs in our stimulus set, Haans and de Kort's findings resulted from a study employing a direct manipulation of lighting distributions in an outdoor environment. It may well be that, while appraisals of the quality of the lighting for a set of photographs of environments do not add predictive value beyond appraisals of the safety-related environmental characteristics for these same environments, the actual experience of different lighting conditions may be more strongly associated with people's immediate perception of safety. As such, our specific design, in which we kept the physical lighting conditions in the cubicles constant for each participant, may partially account for the absence of a direct effect of lighting in our mediation model. More research is needed to test the robustness of the current findings, and clarify how lighting may affect appraisals of safety.

Although the causal directions were specified in the theoretical model, the correlational design of Study 2.2 limited the inference of the causal chains underlying the proposed mediational process (e.g., Spencer et al., 2005). To improve the strength of our claim, we examined the effect of lighting on appraisals of the safety-related environmental characteristics by experimentally manipulating the ambient lighting level in our stimuli in Study 2.3. Although the results indicated an expected increase in appraisals of prospect as we increased the ambient light levels in our virtual environments, we did not find similar effects on appraisals of entrapment and concealment. One potential explanation for the lack of a clear effect of lighting on appraisals of prospect, concealment, and entrapment may be that the specific manipulation of lighting (i.e., increasing the ambient lighting level in a virtual environment) was not sufficiently strong to effect robust changes in appraisals of safety-related environmental characteristics. For example, the effectiveness of our manipulation may have been undermined by the relatively unrealistic ambient lighting level manipulation that did not affect shadows or lighting distribution in the scene. Consequently, our manipulation may have primarily manipulated visibility, a suggestion that fits with our results merely showing an effect of manipulating ambient lighting level on appraisals of prospect.

This latter consideration, regarding the realism of our stimuli and lighting manipulation, also bears on the larger issue of the ecological validity of the current set of findings and how they apply to real-world settings. We have previously justified using photographs of environments and virtual environments as stimuli to increase the range of potential environments, each with its specific configuration of environmental characteristics, and by pointing at studies demonstrating that participants' responses to virtual environments and stimuli presented on screen are comparable to responses obtained in real-life settings (e.g., Stamps, 1993; 2010). Nevertheless, because these studies were not particularly concerned with lighting, a potential issue with the set of studies presented in Chapter 2 is the question to what extent effects of appraisals of the quality of lighting of a set of photographs presented on a monitor screen are comparable to the effects of actually experiencing changes or differences in lighting. Such issues may potentially be overcome by investigating how the experimental manipulation of lighting affects appraisals of the safety-related environmental characteristics in real-world settings (e.g., Haans & de Kort, 2012), or by utilizing fully immersive 3D virtual reality environments – offering a compelling compromise between the experimental control of laboratory settings and the ecological validity of real-world experiences (e.g., Blascovitch et al., 2002). Barring these important considerations, the studies presented in Chapter 2 provide a systematic investigation of the role of lighting in the safety appraisal process and support the idea that lighting affects environmental safety perceptions through its effect on appraisals of safety-related environmental characteristics.

The individual in the proximate environment

The main focus of our studies was understanding how safety-related environmental information (including lighting) from the proximate environment affects appraisals of environmental safety. Yet, in Chapter 1 we acknowledged that more distal individual characteristics may be expected to shape the processing and interpretation of the immediately available information in the proximate environment. A first indication for the existence of these more distal influences in our studies may be the identification of individual differences in susceptibility to safety-related environmental information. For example, depending on individual personality characteristics, preconceptions, and/or prior experiences, some people may perceive the environment as more unsafe when the environment offers low levels of prospect, while other's safety perceptions may not be affected at all by the level of prospect in an environment.

In Chapter 3, we presented two studies in which we investigated individual differences in the weighing of safety-related environmental characteristics, utilizing hierarchical modelling to more accurately model individual-level and stimulus-level contributions to participants' appraisals of environmental safety. Indeed, in Study 3.1, we demonstrated substantial variability in individual susceptibility to safety-related information. For instance, while some participants' demonstrated a substantial decrease in their evaluation of environmental safety following the presentation of environments offering high levels of entrapment, others' appraisals were only minimally affected by the level of entrapment. Moreover, the hierarchical model partitioned the total variance in environmental safety appraisals into individual-level and stimulus-level variance components, and an analysis of these variance components revealed that approximately 30% of the total variance could be attributed to the individual level. These findings from Study 3.1 were closely replicated in Study 3.2[1], extending the perceived safety literature by demonstrating that while the proximate cue framework may provide us with a fundamental understanding of how safety-related environmental characteristics affect the environmental safety appraisal process, the exclusion of individual variation, or the lack of accurately modeling both the individual and the stimulus/environment level influences in our analysis, may hamper a more thorough understanding of how environmental safety perceptions are formed.

1 The findings from Study 3.1 and Study 3.2 demonstrating that approximately one third of the total variance in environmental safety appraisals may be attributed to individual-level influences was also replicated in Study 5.1 and Study 5.2, employing slightly different hierarchical models.

Safety-related individual characteristics

After establishing that substantial individual variation exists in the weighing of safety-relevant environmental information in the environmental safety appraisal process, we explored individual characteristics that are known to be associated with perceptions of safety, and may potentially be responsible for these differences in individual susceptibility to informational cues in the environment. In Study 3.2, we found that appraisals of environmental safety were negatively associated with the individual propensity to experience anxiousness in daily life (i.e., trait anxiety; see also Blöbaum and Hunecke, 2005), but not with the extent to which one perceives oneself an attractive target for potential offenders (i.e., perceived attractiveness; see Haans & de Kort, 2012; van der Wurff et al., 1989), or with the extent to which one perceives oneself able to deal with potentially dangerous situations (i.e., perceived power; see Haans & de Kort, 2012; van der Wurff et al., 1989).

Additionally, in both studies reported in Chapter 3, we replicated an individual-level effect of biological sex on perceived environmental safety (e.g., Fisher & May, 2009; Boomsma & Steg, 2014; Blöbaum & Hunecke, 2005; Fisher & Nasar, 1992), such that females reported lower levels of perceived environmental safety as compared to males. Notably, while the female participants in Study 3.2 reported higher levels of trait anxiety, perceived attractiveness, and perceived power, we extend the literature by showing that the effect of biological sex on perceptions of safety is fully mediated by individual variation in the propensity to experience states of anxiety (i.e., trait anxiety). These findings thus demonstrate how we may successfully employ individual psychological characteristics to explain individual differences in the perception of safety that appear to exist on a biological level.

A large part of the findings from the perceived safety literature showing that men tend to feel more safe in general may thus potentially be explained by lower levels of trait anxiety found in men. The significance of trait anxiety as a potent explanatory variable for understanding the safety appraisal process is further bolstered by the marginalization of the predictive power of other, previously established, safety-related individual characteristics (i.e., perceived attractiveness and perceived power; see Haans & de Kort, 2012; Cossman & Rader, 2011) when trait anxiety was included as individual-level predictor variable in our model in Study 3.2. However, these results require independent replication in order to establish the robustness of the demonstrated effects, and future research may thus be aimed at replicating the prominence of trait and/or state anxiety as an individual-level predictor of environmental safety appraisals, as well as more thoroughly investigating the relationship between trait anxiety and other safety-related environmental characteristics.

Interactions between the environment and the individual

A final contribution of the studies presented in Chapter 3 was that we explored whether the individual-level predictors in our model (i.e., trait anxiety, perceived attractiveness, and perceived power) accounted for the differences in individual susceptibility to safety-related environmental information identified in both studies, by looking at cross-level interactions between the individual-level and stimulus-level predictors in our hierarchical model. In line with our expectations, we found that participants who reported higher levels of trait anxiety assigned more weight to environmental information related to unconstrained visual access to a scene (i.e., prospect), as compared to participants who reported lower levels of trait anxiety.

Although we expected such an interaction on the basis of literature proposing and demonstrating selective attention to safety-relevant information by clinically anxious individuals (e.g., Beck, 1976; Mogg et al., 1993), the question remains why any one individual would be more attentive to certain safety-related informational cues in the proximate environment. One possibility is that, regardless of the configuration of safety-related informational cues within a specific environment, individuals that weigh the available safety-related environmental information more heavily may simply be more inclined to rely on externally available informational cues to develop a perception of the safety of an environment. Given that unpredictability associated with events or stimuli have often been related to anxiety responses (e.g., Riskind, 1997; Katz, 1984; Merckelbach, van den Hout, Jansen, & van der Molen, 1988), individuals with an increased propensity to experience anxiety may have developed a higher need for predictability and, consequently, rely more heavily on external informational cues associated with the level of predictability an environment offers (e.g., prospect).

In addition to a cross-level interaction between trait anxiety and prospect, we found that participants who reported higher levels of perceived power were less affected by environmental characteristics that impede escape opportunities as compared to participants who reported lower levels of perceived power. Provided that we found no interactions between perceived power and appraisals of prospect an concealment, such an interaction does make sense when we take into account the different properties of the safety-related environmental characteristics. While appraisals of prospect and concealment may refer to characteristics related to predictability of the environment and being able to detect potential danger, appraisals of entrapment may be associated more with behavioral control over the environment and refer to environmental conditions that impede actions to keep oneself safe in case of an emergency. Such environmental conditions should be less relevant for those people who are physically able, or at least perceive themselves to be physically able, to deal with potential offenders. In the absence of a sense of personal efficacy in case of immediate danger in the proximate environment, individuals reporting a low level of perceived power may place more weight on, and selectively attend to, information regarding the extent to which the environment offers behavioral control – a process that is similar to the proposed process underlying the interaction between anxiety and the weighing of information related to the predictability of the environment.

However, it is important to note that the person-environment interactions we identified in Study 3.2 were relatively small (i.e., they did not account for large parts of the variance in susceptibility to safety-related environmental characteristics; see *Table 3.8*), and, in addition, the remaining seven interactions we tested yielded no significant interactions. On the one hand, these findings may lead one to suggest that cross-level interactions are simply marginal or even nonexistent in the real world. Yet, given the substantial individual differences in susceptibility to safety-related environmental characteristics that we identified in both studies presented in Chapter 3, we believe there is ample room for future research to examine other safety-related individual characteristics that may better account for these individual differences in environmental safety perception. For example, while we focused on the relatively stable individual trait anxiety to represent the idea that more anxious people attend selectively to safety-relevant informational cues, it may also be interesting to actually record, or manipulate, participant's current state of anxiety, to see whether participants' current psychological state yields more conclusive results with regard to accounting for differences in the weighing of safety-related environmental information in the safety appraisal process.

Importantly, although the effects are not very large, these findings do provide initial evidence for the existence of interactions between psychological characteristics on the individual level and appraisals of safety-related environmental characteristics.[2] Moreover, building on findings demonstrated in a population of clinically anxious people (e.g., Mogg et al., 1993), our studies provide one of the first systematic demonstrations of a theory-driven hypothesized interaction between the individual and the environment in the safety appraisal process. These findings highlight the importance to move away from a framework of safety perceptions that regards environmental characteristics and individual characteristics as largely isolated contributing factors, and instead call for the adoption of a framework

2 Blöbaum and Hunecke (2005) also provide evidence for an interaction between biological sex and appraisals of entrapment. However, the studies presented in Chapter 3 focus more thoroughly on understanding not only individual-level characteristics related to biological differences, but the potential safety-related psychological differences that underlie such an interaction (see our discussion on the effect of biological sex on perceived environmental safety), and provide a more systematic investigation of individual-level and environmental-level influences using hierarchical modelling to account for variation that may be attributed to either level of interest.

that acknowledges the intricate interaction between the person and the environment in the safety perception process.

Moreover, given the dynamic relationship between the individual and the environment, our findings suggest that the mere identification of determinants of perceived environmental safety is not sufficient. Acknowledging the dynamics in safety appraisals processes may be relevant for studies aimed at identifying a pedestrians' critical tasks, as the nature of what is important for our sense of safety (e.g., critical tasks) may change dependent on, for example, the current psychological state of the pedestrian, or the specific environmental context. For instance, with respect to the distance at which a pedestrian requires a basic sense of the intent of another street user, this critical distance may be larger in environments that offer high levels of entrapment and concealment, and a low level of prospect, as compared to environments that show an opposite configuration of safety-related environmental characteristics – a proposition that has recently received some preliminary support in a study performed on the campus of Eindhoven University of Technology (Berghuis, den Hartog, Romijn, & Haans, 2014).

Temporal aspects of safety appraisals

In Chapter 4, we presented two studies utilizing a (rapid) dichotomous safety categorization task, in which we examined the time course of the safety appraisal process. In Study 4.1, we found that participants, when instructed to respond as quickly and accurately as possible while maintaining confidence in their judgment, categorized stimuli relatively fast with respect to perceived environmental safety and perceived prospect (~ 1 second). Study 4.2 extended these findings by demonstrating that our participants were capable of accurately categorizing rapidly presented (≤ 150ms) scenes of nocturnal urban environments with respect to perceived environmental safety. These findings fit within the broader literature on natural scene perception that has demonstrated that many perceptual tasks (e.g., object detection or basic scene categorization) may be achieved within a time-span of 150ms (Thorpe et al., 1996; Bacon-Macé et al., 2005; Grill-Spector & Kanwisher, 2005; Greene & Oliva, 2009; Fei-Fei et al., 2007). Importantly, our findings extend the literature on natural scene perception by demonstrating that appraisals of environmental safety – which we argued are more complex than appraisals of global environmental characteristics as well as more dependent on subjective interpretations of the environment as compared to object detection and basic-level categorization tasks – are also accurately achieved within 250ms (i.e., the time between stimulus onset and visual masking procedure). Moreover, as well as providing evidence for the idea that the safety appraisal process is a rapid process that requires minimal cognitive effort (e.g., Parsons, 1991), these findings support the general functionalist perspective on environmental perception as outlined in Chapter 1, which emphasizes that the processing of environmental information is one of the most important evolutionary-shaped mechanisms for human adaptive functioning in the environment (e.g., Brunswik, 1952; Kaplan & Kaplan, Appleton, 1975; 1984).

Masking the available environmental information

The significance of the processing of relevant environmental information was further demonstrated in the studies presented in Chapter 5, in which we employed a masking paradigm to manipulate the amount of available environmental information. The impairment of obtaining a sufficient amount of information from the environment was expected to negatively impact the safety appraisal process, leading to decreased confidence in perceptual judgments about the environment. Indeed, the results from Study 5.1 and Study 5.3 revealed that increases in the amount of random masking of available environmental information was associated with lower decision confidence in both evaluation (Study 5.1) and categorization (Study 5.3), and reported levels of decision confidence were found to be correlated to both environmental safety appraisals and response accuracy. In addition, randomly masking environmental information was associated with lower evaluations of environmental safety, and with reduced accuracy on a dichotomous categorization task in which participants categorized stimuli depicting nocturnal urban environments with regard to the safety of the environment.

Despite the limited leeway afforded by the design of the studies presented in Chapter 5 for inferring the underlying causal mechanisms, we may identify two potential pathways through which masking information may affect decision confidence and appraisals of environmental safety. On the one hand, we may observe decreased decision confidence after masking environmental information because there are simply insufficient informational cues available to warrant a confident environmental appraisal. On the other hand, because many informational cues are redundantly specified in environmental space (e.g., an environment may provide many sources of information about possibilities for escape in case of an emergency), it may not necessarily be the insufficiency of available informational cues that diminish the confidence in achieving accurate environmental appraisals, but the mere awareness of missing potentially important information. Future research may be aimed at further investigating the role of decision confidence in the safety appraisal process by designing studies that further specify the (perhaps causal) relationship between decision confidence and environmental safety appraisals, as well as identify the pathways through which the masking of environmental information affects decision confidence and appraisals of environmental safety.

In addition to investigating the effects of randomly masking environmental information, we examined how locally masking certain areas within the environment affected the environmental safety appraisal process. In Study 5.2, we found that increasing the position of a dense masking band from the bottom of our stimuli (i.e., the immediate environment) toward the horizon (i.e., the more remote environment) was associated with more negative appraisals of environmental safety and lower reported decision confidence. However, the results from Study 5.3 showed a contradictory pattern. For the first of our two operationalizations of the immediate and remote environment (i.e., low mask versus high mask), we replicated the results of Study 5.2, with a decrease in participants' performance in the categorization task and lower reported decision confidence associated with masking the remote environment. In contrast, for the other operationalization (i.e., window mask versus scotoma mask), we found that masking the immediate environment was associated with decreased performance and lower decision confidence. However, considering only the areas covered by the effective masks (i.e., the high mask and the window mask), we identified two areas in the horizontal periphery of the stimuli (see *Figure 5.6a*) that seem to impact the safety appraisal process more strongly as compared to other areas. Thus, despite the apparent difficulties in operationalizing a differentiation of environmental space in an immediate environment and a more remote environment (see also Chapter 5 and next section), which put a limit on the extent to which we may generalize the findings from the studies presented in Chapter 5 to our actual experience of environment space, our results do empirically demonstrate that people differentiate environmental space (e.g., Goffman, 1971; Hall, 1966; Cutting & Vishton, 1995), and that the acquirement of safety-relevant information is distributed accordingly.

Methodological musings

In addition to the theoretical contributions discussed in the previous sections, the studies presented in the current thesis also contribute to the perceived safety literature by employing methodological tools and approaches that provide novel ways to examine the safety appraisal process in a laboratory setting. In the current section, we will focus on the most important methodological contributions, identify potential limitations and provide suggestions for potential improvement, and suggest how these methodological tools may be implemented in future research aimed at understanding the safety appraisal process.

Investigating temporal aspects of safety appraisals

One of the ways in which we attempted to gain a better understanding of the safety appraisal process, was through examining the time needed to extract sufficient environmental information from a stimulus to achieve accurate and confident appraisals of environmental safety. To investigate these temporal aspects of the safety appraisal process, we extended the literature by introducing a rapid presentation procedure that is more commonly employed by research endeavors investigating the time course of natural scene gist perception (e.g., Fei-Fei et al., 2007; Thorpe et al., 1996; Bacon-Macé et al., 2005; Grill-Spector & Kanwisher, 2005; Greene & Oliva, 2009).

Yet, while the results are in line with the literature on scene gist perception, supporting our claim that people are capable of rapidly deciding whether an environment is safe or unsafe, we noted that the specific design of Study 4.2 – manipulating the presentation time of the stimuli while keeping total processing time constant at 250ms – does not allow a more detailed characterization of the time-course of environmental safety perceptions. As the time between stimulus onset and visual masking procedure was kept constant, we could not distinguish between the influence of processes that rely on pure sensory information and processes that rely on information from the visible persistence of sensory information or on information available in iconic memory. However, future research may employ similar rapid presentation procedures to extend the current findings and test more rigorously the various potential processes that underlie the rapid processing of safety-relevant information. For example, keeping the stimulus presentation time constant and manipulating the time between stimulus onset and a visual masking procedure may gain us a better understanding of the particular contribution of direct visual information versus information gained from the processing of indirect visual information (e.g., from visible persistence of the stimulus or from iconic memory).

Reducing the information available in a stimulus

To examine the role of information-processing in the safety appraisal process in more depth, we employed a novel masking paradigm in Chapter 5 that was aimed at reducing locally targeted information from our stimuli. The basic mask, consisting of a large number of circles cut out from a main opaque base stimulus overlay (see e.g., *Figure 5.1*), was complemented by a masking band that effected a higher masking density as compared to the basic mask (see e.g., *Figure 5.2*). This paradigm thus allowed us to block specific environmental regions within our stimuli and observe participants' responses with regard to judgments about the perceived safety of the environment. The effectiveness of our masking paradigm was demonstrated both in Study 5.1, in which reducing the availability

of environmental information randomly across our stimuli was associated with lower perceptions of environmental safety and decision confidence, and in Study 5.2, in which the targeted masking of specific environments was associated with differences in participants' judgments about the safety of the presented environments.

However promising the current novel (rapid) masking paradigm is for researchers interested in discretely investigating how masking certain regions in a stimulus depicting a natural scene affects the perception of this natural scene, we have identified some important concerns which currently still limit a fully accurate interpretation of the results from our studies. In essence, these concerns boil down to the central issue of how we may realistically translate the complex and potentially dynamic divisions of environmental space into masking bands that correctly represent these spatial distances in 2D photographic depictions of natural scenes (these issues are more extensively discussed in Chapter 5). For example, we have noted that our current operationalizations of the immediate and remote environment in our stimulus masks did not seem to accurately reflect the theoretically distinguished divisions of environmental space. Future research could thus focus on extending the current (rapid) masking paradigm by developing more realistic masking overlays that more accurately reflect division of environmental space as we perceive them in the real world. Moreover, research should be appropriated to extending the current masking paradigm to immersive virtual reality settings and/or the physical environment (e.g., by developing glasses that effect a similar masking effect).

Despite these suggestions for improvement, we believe the masking paradigm is a promising methodological tool for investigating the effect of manipulating certain informational cues from the environment, and that it may be successfully employed in other research settings as well. One useful application of the current masking paradigm is that it may be used to verify the results obtained from eye-tracking studies that examine critical tasks for pedestrians, for example by examining how the masking of the critical events and/or objects identified through eye-tracking affect people's (safety-related) judgments about the environment.

Range bias

In Chapter 4, we compared safety responses obtained with five-point response category format measures with safety responses obtained with a dichotomous categorization task. These scaled response category format measures have been associated with a number of response biases (e.g., Daamen, 1991; Poulton, 1989; Fotios et al., 2015). For example, people presented with a certain scale range (e.g., from "not at all" to "very much") in an evaluation task, tend to utilize the full range of the scale to indicate relative differences between the evaluation objects in an evaluation set. As a consequence, the absolute evaluations obtained with a certain set of stimuli may differ from absolute evaluations obtained with a different, more broadly (or narrowly) sampled, set of stimuli.

The existence of a such a potential range bias in the responses obtained from our five-point response category format measures was implied by the results from the studies presented in Chapter 4. Because the two stimulus categories (safe vs unsafe) employed in these studies comprised stimuli that, based on the evaluations of the participants in Study 2.1, were similarly but oppositely distributed around the mid-point of the rating scale (see X-axis in *Figure 4.3*), we would expect the proportions of categorization responses to be roughly equal. Yet, in these studies participants demonstrated an overall tendency towards categorizing stimuli as safe, as well as a lower accuracy for stimuli from the 'unsafe' stimulus category. Furthermore, inspection of the accuracy distribution in *Figure 4.3* illustrates how some of the less extremely evaluated stimuli from the 'unsafe' category were more difficult to categorize, suggesting that we should be cautious in relying on numerical ratings from rating scales to assign evaluation objects into categories. More convincingly, Fotios and colleagues, employing our measures of perceived environmental safety (see Appendix B) and our set of 100 stimuli, have recently indeed demonstrated a range bias in participants' evaluations of perceived environmental safety (Fotios et al., 2015). The complete set of stimuli were ranked according to the evaluations obtained from Study 2.1 and split into two subsets of 55 stimuli, after which participants were subjected to the same evaluation procedure employed in Study 2.1 for each of the two subsets. Their results demonstrated that the stimuli that overlapped in both stimulus sets (ranks 46 through 55) were evaluated much more positive as part of the more 'unsafe' set (ranks 1 through 55) than as part of the more 'safe' set (ranks 46 through 100), thus providing evidence for a range bias in our measures of perceived environmental safety.

The main concern with the identification of a range bias in our measures of perceived environmental safety is that we cannot necessarily rely on the numerical ratings assigned by our participants in the evaluation tasks (e.g., Fotios & Houser, 2009; Fotios et al., 2015). Even though most of the analyses in the current thesis rely on relative differences (e.g., correlations, regression) as opposed to absolute ratings, we should be cautious with assuming these relative differences are not affected by range bias. Therefore, it seems appropriate to complement measures that are known to be vulnerable to range bias (or other types of response biases) with other, more bias-free, measurement paradigms (e.g., pairwise comparisons; see Fotios & Houser, 2009). Future research may thus be directed at further examining the implications of range bias for the reliability of relative differences in subjective evaluations of environmental safety perceptions, and focus on designing studies in which different measures of environmental safety may be compared with one another.

Representative design

The importance of presenting participants with representative stimuli in psychological experiments was explicitly recognized as early as the 1940s (e.g., Brunswik, 1944), but remains largely ignored in many studies today – or misinterpreted to denote that understanding true patterns of behavior requires observation of behavior that occurs in actual real-world settings. Instead, an important point put forward by Brunswik and other advocates of representative design is that we should construct our stimuli in such a way that environmental properties and their interrelationships remain as intact as possible – thus shunning the study of too abstract representations of reality (e.g., Brunswik, 1944; 1955; Dhami, Hertwig, & Hoffrage, 2004).

In our discussion of research applying the proximate cue framework to understanding how safety-related environmental characteristics affect perceptions of safety (e.g., Fisher & Nasar, 1992; Loewen et al., 1993; Blöbaum & Hunecke, 2005), we identified some potential issues with regard to the representative nature of the designs commonly employed in this domain of research. For instance, the explicit focus on a limited set of environments, sometimes within areas that are, according to the authors, notorious for the incidence of crime after dark (see e.g., Fisher & Nasar, 1992), and selected to exhibit certain predefined configurations of safety-related environmental characteristics (e.g., high prospect, and low concealment and entrapment), may insufficiently reflect the everyday situations in which we form our perceptual judgments.

One way to achieve more representative stimuli is extending the methodological rigor that is commonly exerted with regard to the random sampling of participants to the random sampling of the stimuli used in our experiments (e.g., Brunswik, 1955; Hoffrage & Hertwig, 2006), for example by considering whether the range of stimuli used in the experiment sufficiently reflects the range of environments, objects, or events that one desires to generalize to. Analogous to the more widely recognized notion that observed effects may depend on the specific population sample that is tested (e.g., Henrich, Heine, & Norenzayan, 2010), observed effects may also depend on the range of stimuli included in the experimental design. For example, the validities of predictor variables have been shown to vary as a function of the inclusiveness of the reference class of stimuli (e.g., Dhami et al., 2004; Hoffrage & Hertwig, 2006).

Thus, the range of stimuli included in the experiment may determine the range of stimuli participants consider when making judgments about an environment. While past research may have identified strong cue validities for appraisals of prospect, concealment, and entrapment, the reference class population of environments (i.e., the type of environments considered by participants) in these studies is rather limited and the question is to what extent the cue validities generalize to a broader reference class of environments (e.g., other types of environments besides a university campus). Hence, an explicit goal of the work presented in the current thesis was to validate the important role of safety-related environmental characteristics identified in previous research by collecting safety-related responses to a large set of photographs depicting environments that our participants may encounter on a daily basis.

A number of our studies have successfully extended the support for the prominence of appraisals of the safety-related environmental characteristics within the wide range of environments we presented to participants. However, we also noted that on the whole, the effects of appraisals of safety-related environmental characteristics were smaller than the effects typically identified in the literature, especially with regard to the effects of appraisals of prospect and concealment. While it may be the case that these type of effects are generally stronger in the real-world settings commonly employed as stimuli in this type of research, the preceding discussion on representative design presents a feasible alternative explanation for the discrepancy in the magnitude of the effect of appraisals of safety-related environmental characteristics. That is, the relative strength of the predictors (i.e., high cue validities) found in these studies may merely reflect the relationship between the safety-related environmental characteristics and environmental safety appraisals for the limited reference class of environments that are represented by sampling from a relatively homogenous environmental setting (e.g., a university campus) those environments that exhibit 'extreme' configurations of prospect, concealment, and entrapment.

Boundaries on representativeness in the current work. Although we believe that the selection of the environments comprising our stimulus set represents a significant improvement over previous work with regard to presenting an inclusive set of environments to participants, we may nonetheless identify a number of limitations that moderate the representativeness of the data both on the stimulus level and the participant level. On the stimulus level, the sampling of environments reflects on-site decisions 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 selecting environments by means of more thorough random selection methods. In addition, pending extension of our findings to other types of environments besides nocturnal urban environments (e.g., rural or natural environments), the currently presented conclusions apply primarily to urban, night-time environments. We cannot yet be certain that our findings generalize to different types of environments, such as more rural or natural environments, or even to the same urban environments by day.

A final limitation with respect to the representativeness of the stimuli used in our experiments is that we explicitly excluded the presence of other people from the environments depicted on our stimuli. Hence, the explicit focus on the role of environmental and individual factors influencing our sense of safety omits the potentially substantial role of social factors in the safety appraisal process. For example, it may be possible that the mere presence of other people diminishes the primacy of safety-related environmental cues, and instead focuses an observer primarily on the available social cues. It will thus be interesting to investigate what happens to the environmental safety appraisal process, for example in terms of the magnitude of safety evaluations, when we introduce the social presence of others in the environments under consideration.

On the participant level, as our samples were mostly recruited from Eindhoven University's J.F. Schouten participant database, we primarily made use of convenience sampling. While the distribution of sexes and the age range (18 to 78 years old) across our samples may be considered a representative reflection of the reference class adults, the main body of participants were university students (M_{age} ~26 years old). The consequence of relying on such a relatively narrow sample is that our findings may not generalize well to a broader and more diversified population.

Thus, to further extend the generalizability of the findings presented in the current thesis, future research may be aimed at addressing these potential issues and extend our findings beyond (a) our limited class of environments, and (b) the relatively narrow sample of participants.

Findings in context

In view of recent trends and innovations in lighting design, we have formulated the main goals of the current thesis in the broader context of a reappraisal of current lighting recommendations, and identified a need for better understanding how environmental characteristics (including lighting) affect safety perceptions. Although the bulk of the work we have presented strongly focused on understanding the mechanisms underlying the use of safety-related informational cues from the environment in the environmental safety appraisal process, we may provide some tentative implications of our findings pertaining to the broader context of lighting design and lighting recommendations.

First, in Chapter 2 we found that while appraisals of the quality of the lighting accounted for a large part of the variance in perceived environmental safety, these lighting appraisals did not demonstrate predictive value beyond appraisals of the safety-related environmental characteristics. Moreover, in line with recent work in which lighting distributions were manipulated in an outdoor setting (Haans & de Kort, 2012), we found that the influence of appraisals of the quality of the lighting on perceptions of environmental safety was mediated by the influence of appraisals of the quality of the lighting on appraisals of safety-related environmental characteristics. Keeping the limitations identified in the discussion of our results in mind, these findings suggest that lighting may primarily influence appraisals of environmental safety through its effect on safety-related environmental characteristics (e.g., appraisals of prospect).

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). Adopting a more broad application perspective, our findings suggest that optimizing the uniformity of the lighting distribution in any given setting, 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 focussing more specifically on examining the suggested link between lighting characteristics and safety-related informational cues in the environment.

Second, the results from the studies we presented in Chapter 5 provide support for the notion that the perception of environmental space is differentiated (e.g., Goffman, 1971; Hall, 1966), and that retrieval of informational cues is adapted accordingly. A potential implication of this differentiation of environmental space is that lighting requirements may also vary according to these functional spaces. Indeed, recent work has demonstrated that lighting affects safety perceptions and appraisals of safety-related environmental characteristics primarily in the immediate environment (Haans & de Kort, 2012; Viliûnas et al., 2013). However, what constitutes the immediate environment and the remote environment may depend on a number of factors, such as the mode of transport (e.g., cyclist vs pedestrian) or the presence of other people. The masking paradigm described in Chapter 5 may prove to be a useful tool to improve lighting recommendations, but it will require more research to examine more thoroughly the relevant subdivisions of environmental space, both with regard to factors that determine how environmental space is differentiated by the individual, and the potential differences in lighting requirements.

Finally, the findings from Chapter 3 demonstrate how the propensity of an individual to experience states of anxiety, in addition to a general effect on appraisals of environmental safety, may influence the way in which safety-relevant information is weighted in the safety perception process. This dynamic interaction between the individual and the (perception of the) environment presents an interesting point for studies identifying the critical tasks for developing a sense of safety (e.g., Davoudian & Raynham, 2012; Fotios et al., 2014); do feelings of insecurity, for example resulting from a specific configuration of environmental characteristics, change what is critical in terms of the perceptual tasks that need to be completed? In other words, do our visual priorities depend on the characteristics of our surroundings? Preliminary evidence for this proposition is provided by a recent study performed on the campus of the Eindhoven University of Technology, in which participants were instructed to walk towards a hooded confederate and halt at the point where they stopped feeling comfortable, requiring more information about the intentions of the confederate (Berghuis et al., 2014). In line with what was expected, participants maintained larger interpersonal distances in environments that were evaluated as unsafe (offering reduced prospect and opportunities for escape). However, given that reported comfortable distances in the literature vary considerably across studies, and seem to depend greatly on the procedure used to elicit participants' responses (e.g., Fotios & Yang, 2013), these results will need to be validated using different experimental procedures. Future work investigating critical visual tasks may thus focus on further investigating how environmental characteristics and current psychological state (e.g., state anxiety) influence the visual tasks that are deemed important for developing a sense of safety.

General limitations

Throughout our discussion in the current chapter, we have identified specific limitations, considerations, and areas for future improvement. Still, we may additionally identify a number of more general limitations that broadly apply to the work presented in the current thesis.

Although we have repeatedly demonstrated the importance of appraisals of safety-related environmental characteristics in the safety appraisal process, our results rely primarily on evaluations of static environments. As such, we have mainly been concerned with the role of safety-related environmental characteristics in achieving an immediate impression of the safety of an environment. However, the role of appraisals of environmental characteristics may change as one progresses through an environment, as, after an initial appraisal phase, the individual may be expected to allocate most resources to monitoring changes in the environmental setting rather than to constantly reappraising the environment (e.g., Wang & Taylor, 2006).

Moreover, the focus on one-shot appraisals of the environment omits the dynamic interaction that characterizes the relationship between an individual and the environment. Rather than being entirely dependent on physical characteristics of the surroundings, the individual is expected to shape his or her own safety feelings through behavioral and/or cognitive coping strategies. For example, Painter (1996) found that women had altered their demeanor and walking speed, and started to walk on the pavement rather than on the road after public lighting improvements were implemented. Similarly, the results from the study by Berghuis and colleagues (2014) indicate that pedestrians may maintain larger interpersonal distances in environments that are deemed unsafe. Such behavioral coping strategies may offer a sense of compensatory control (e.g., Landau, Kay, & Whitson, 2015; Kay, Whitson, Gaucher, & Galinsky, 2009) in environments that are perceived as offering low levels of cognitive and behavioral control. More research is needed to examine how the role of safety-related environmental characteristics changes as individuals travel through an environment, and which coping strategies are typically employed to deal with environmental influences on feelings of safety.

Another limitation of the studies presented in the current disseration is that the studies were performed during the day in a safe and controlled laboratory setting. Although the participants were instructed to imagine walking alone in the depicted environments, their presence in our safe laboratory on the university campus will most likely not have elicited the same emotional state as actually walking alone in public space at night. While we did not explicitly measure the level of anxiousness participants experienced at the time of participation, we assumed that most people were generally at ease. The current findings may thus be extended by investigating how the experience of anxiety affects the environmental safety appraisal process. We may achieve heightened levels of anxiety in an experimental setting through induction of an anxious emotional state (i.e., state anxiety) by means of, for example, movies (excerpts) that have been demonstrated to increase anxiety (e.g., Schaefer, Nils, Sanchez, & Philippot, 2010; Gross & Levenson, 1995).

In addition to potential differences in participants' emotional state between our lab setting and a more typical outdoor setting, recent work suggests that time of the day moderates attention to contextual information, demonstrating increased attention and more intense reactions to fear-related stimuli at nighttime as compared to daytime (Li et al., 2015). While the role of safety-related environmental characteristics has been demonstrated by previous studies during daytime as well as during the night (e.g., Fisher & Nasar, 1992; Blöbaum & Hunecke, 2005; Boomsma & Steg, 2014), other findings presented in the current thesis may be extended by examining whether time of the day significantly alters the environmental safety appraisal process as we currently understand it.

On a final note, because we have primarily focused on appraisals of safety and safety-related characteristics in the proximate environment, the scope of the current thesis is limited to but a part of a larger array of factors that may influence our sense of safety (e.g., socio-cultural influences; see Chapter 1). Although we have extended our understanding of the environmental safety process, the relationship between such environmental appraisals and the experience of a sense of personal safety is still unclear. More research is needed to examine the relationship between measures of environmental safety appraisals and other measures and indices of perceived safety, and determine the extent of the contribution of environmental safety appraisals to the experience of safety.

Conclusion

The primary aim of the work presented in the current thesis was to develop a theoretical understanding of the appraisal process through which physical characteristics of the environment affect the immediate perception of the safety of an environment. Employing a representative set of nocturnal urban environments, our findings repeatedly validate previous findings from the safety literature, demonstrating the important role of appraisals of safety-related environmental characteristics (i.e., prospect, concealment, and entrapment) in the environmental safety appraisal process. In addition, our findings demonstrate substantial individual differences in susceptibility to these safety-related informational cues, and extend the literature by identifying individual characteristics that directly affect environmental safety appraisals as well as interact with appraisals of safety-related information. With regard to understanding the role of lighting in the environmental safety appraisal process, our findings provide preliminary support for the idea that lighting may affect appraisals of environtal safety through its effect on appraisals of safety-related environmental characteristics.

In line with the functionalist information-processing perspective we adopted, the findings from the studies we presented in the current disseration underscore the importance of processing relevant informational cues from the environment. We extended the natural scene perception literature and perceived safety literature by demonstrating that people are capable of rapidly extracting sufficient relevant environmental information to achieve accurate appraisals of safety. Moreover, our findings indicate that impairing the retrieval of informational cues from the environment by masking relevant information leads to decreased evaluations of perceived environmental safety and lower decision confidence. Finally, our results provide preliminary evidence for the notion that retrieval of relevant (safety-related) informational cues from the environment corresponds to perceptually differentiated functional spaces within the broader environmental space.

In sum, despite the limitations identified in our discussion, the findings from the work presented in the current thesis contribute to the development of a theoretical understanding of the environmental safety appraisal process, and may benefit a more empirical, and thus justifiable, foundation for designing measures aimed at enhancing experiences of safety in public space, including the design of novel public lighting implementations.

Appendix A

Simulated environments

The three simulated environments used in Study 2.4 and their respective renderings with increased ambient lighting.

Rural footpath enclosed by dense trees and shrubbery. (A) base rendering, (A’) ambient lighting intensity 0.2, (A”) ambient lighting intensity 0.4.

Tunnel. (B) base rendering, (B’) ambient lighting intensity 0.2, (B”) ambient lighting intensity 0.4.

Residential street. (C) base rendering, (C’) ambient lighting intensity 0.2, (C”) ambient lighting intensity 0.4.

Appendix B

Measures

Items measuring *prospect* (adapted from Haans & de Kort, 2012)
1. How good or poor an overview do you have over this environment?
2. How well or poorly can you see what is happening in this environment?
3. How well or poorly can you see objects in this environment?

Items measuring *concealment* (adapted from Haans & de Kort, 2012)
1. How easy or hard is it for ill-intentioned people to find a hiding place in this environment?
2. Are there many or few areas in this environment where a potential criminal can hide?
3. How large or small is the probability that an ill-intentioned person hides in this environment?

Items measuring *entrapment* (adapted from Haans & de Kort, 2012)
1. How large or small is the probability that you can escape this environment in case of an emergency?
2. How easy or hard is it to bring yourself into safety in this environment?
3. How hard or easy would it be for an ill-intentioned person to entrap you in this environment?

Items measuring *perceived environmental safety* (adapted from Haans & de Kort, 2012)
1. How safe or unsafe do you judge this environment?
2. How uneasy or comfortable do you feel with the idea of having to walk into this environment?
3. To what extent would you normally avoid or not avoid an environment like this during a nightly stroll?

Items measuring *perceived quality of the lighting*
1. How good or poor do you think the quality of the lighting is in this environment?
2. Is the quality of the lighting in this environment better or worse than in other comparable nocturnal urban environment?
3. Is the quality of the lighting in this environment better or worse than in other comparable nocturnal urban environment?
4. How dark or light do you think this environment is?
5. Is there too little or too much light in this environment?
6. How dark or light is this environment in comparison to other urban environments at night?

Items measuring *trait anxiety* (STAI form Y2; adapted from Blöbaum & Hunecke, 2005)
1. I feel pleasant
2. I feel nervous and restless
3. I feel satisfied with myself
4. I wish I could be as happy as others seem to be
5. I feel like a failure
6. I feel rested*
7. I am calm, cool, and collected
8. I feel that difficulties are piling up so that I cannot overcome them
9. I worry too much over something that doesn't really matter
10. I am happy
11. I have disturbing thoughts*
12. I lack self-confidence
13. I feel secure
14. I make decisions easily*
15. I feel inadequate
16. I am content
17. Some unimportant thought runs through my mind and bothers me
18. I take disappointments so keenly that I can't put them out of my mind
19. I am a steady person
20. I get in a state of tension or turmoil as I think over my recent concerns and interests

** items removed after principal axis factor analysis revealed factor loadings smaller than .5*

Items measuring *perceived attractiveness to crime* (adapted from Haans & de Kort, 2012)
1. To what extent do you regard yourself an attractive or unattractive target for potential offenders?
2. How large or small is the likelihood that a possible criminal will select you as a target?
3. To what extent do you regard yourself an easy or hard target for criminals?

Items measuring *perceived power* (Haans & de Kort, 2012)
1. To what extent do you regard yourself incapable or capable of escaping from an attacker?
2. To what extent do you regard yourself incapable or capable of chasing off an attacker?
3. To what extent do you regard yourself incapable or capable of defending yourself against a potential attacker?

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Summary

Shedding light on safety perceptions

The substantial increase in novel and technology-driven public lighting solutions (e.g., intelligent dynamic street lighting), aimed at reducing societal issues around energy waste and lighting pollution, raises important new questions with respect to the design of public lighting. For example, while novel technologies may facilitate efficient and well-targeted lighting, as of yet it remains unclear where people need light, or indeed how much light they actually need in order to feel safe. Current public lighting recommendations, developed within the context of conventional lighting systems and often based on scant empirical evidence, may not be sufficient any longer in the context of these new type of questions, thus presenting us with a momentum for reconsidering the adequacy and empirical foundations of these recommendations. Within this context, the main aim of the work presented in the current thesis was to better understand the role of lighting in the safety appraisal process. More specifically, the aim was to develop a theoretical understanding of the appraisal process through which physical characteristics of the environment (including lighting) affect the immediate perception of the safety of an environment. The issue was approached from an environmental psychology perspective, in which we emphasized the importance of processing safety-relevant information from the environment, examined how safety-related appraisals of the environment affect people's perception of the safety of an environment, and investigated the role of lighting in the broader safety appraisal process.

In Chapter 2, we presented a set of four studies in which participants evaluated (simulated) nocturnal urban environments with respect to perceived environmental safety, perceived quality of the lighting, and perceptions of safety-related characteristics of the environment. The studies support previous findings showing how a large portion of variance associated with environmental safety appraisals is accounted for by environmental appraisals of entrapment (perceived escape possibilities), prospect (perceived overview over a scene), and concealment (perceived environmental affordance of hiding places for criminals). Additionally, the results suggest that perceptions of the quality of the lighting affect environmental safety appraisals through the effect of lighting on these safety-related environmental characteristics.

In Chapter 3, we presented two studies that extend the main findings from Chapter 2, employing multi-level modeling to examine how both safety-related environmental characteristics and individual characteristics influence appraisals of environmental safety. The results of the studies again provide evidence for the importance of appraisals of safety-related environmental characteristics. More importantly, the studies provide a systematic investigation of person-environment interaction in the safety appraisal process. The results revealed substantial individual variability in the susceptibility

to safety-related environmental characteristics and identified an interaction between personality characteristics (e.g., trait anxiety) and appraisals of environmental characteristics. Additionally, while both studies replicated a large effect of biological sex on safety perceptions, our results indicate that this effect is explained by sex differences in trait anxiety.

In Chapter 4, we examined how much time is needed to extract sufficient information from the environment to achieve accurate appraisals of environmental safety. In two studies, we explored participants' accuracy in a categorization task under various stimulus presentation times (17ms - 150ms). The results from these studies provide evidence that people are capable of rapidly extracting relevant environmental information from the environment to achieve accurate appraisals of environmental safety. In addition, the high agreement between safety responses obtained using the dichotomous categorization task and safety responses obtained using the five-point response category format measures in earlier chapters, indicate that our measurements of perceived environmental safety are robust across different methods.

The aim of the studies presented in Chapter 5 was to further extend our understanding of the environmental safety appraisal process by exploring how the masking of environmental information affects environmental safety appraisals and the confidence in these appraisals. More specifically, we examined whether information-seeking is adapted to psychological differentiations of environmental space. In line with the information-processing account of environmental perception, our results indicate that masking random information from the environment is associated with more negative appraisals of environmental safety and a decrease in decision confidence. Furthermore, our results demonstrate that people differentiate environmental space, and that the acquirement of safety-relevant information is distributed accordingly.

The work described in the current thesis validates previous work highlighting the important role of appraisals of safety-related environmental characteristics in the safety appraisal process using a representative sample of everyday nocturnal urban environments. Moreover, it extends the literature by showing that (a) the effect of (perceptions of) lighting may be fully accounted for by the effect of (perceptions of) lighting on appraisals of the safety-related environmental characteristics, (b) large individual differences exist in the susceptibility to these environmental characteristics, and (c) how personality characteristics directly affect safety appraisals as well as interact with appraisals of safety-related information in the environment. Finally, our results provide preliminary evidence for the notion that retrieval of relevant (safety-related) informational cues from the environment corresponds to perceptually differentiated functional spaces within the broader environmental space. These findings contribute to the further development of a theoretical understanding of the environmental safety appraisal process, and may benefit a more empirical, and thus justifiable, foundation for designing measures aimed at enhancing experiences of safety in public space, including the design of novel public lighting implementations.

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Curriculum Vitae

Leon van Rijswijk was born in 1983 in Zwijndrecht, the Netherlands. After graduating from Insula College Dordrecht in 2002, he studied Psychology at Tilburg University, where he obtained his B.Sc. degree in Psychology with distinction in 2009 and his M.Sc. degree in Social Psychology cum laude in 2010. During his studies at Tilburg University, Leon worked as a research assistant for the Tilburg Institute for Behavioral Economics Research (TIBER).

From June 2011, Leon pursued a Ph.D. degree from Eindhoven University of Technology. His work focused on investigating the role of environmental information on perceptions of environmental safety, with special attention for the role of lighting in the safety appraisal process. For the duration of his Ph.D. project, he was employed within the Human-Technology Interaction group at Eindhoven University of Technology and was an affiliated researcher in the Brilliant Streets and Sound Lighting program lines of the Intelligent Lighting Institute (ILI). Leon is a board member of the Dutch Light and Health Research Foundation (SOLG), a non-profit organization which aims to develop and disseminate knowledge about light and its relationship to health, wellbeing, and performance.

From December 2015, Leon works as a scientific researcher at the Dutch Tax Administration in Utrecht.