The Downside of Building Up: An Exploration into the Psychological and Physiological Impacts of Exposure to High-Rise Buildings

by Robin Mazumder

A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Doctor of Philosophy

in Psychology

Waterloo, Ontario, Canada, 2020

Examining Committee Membership

The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

External Examiner	Dr. Upali Nanda Adjunct Professor
Supervisor	Dr. Colin Ellard Professor
Internal Member	Dr. Michael Dixon Professor
	Dr. Roxane Itier Associate Professor
Internal-external Member	Dr. Markus Moos Associate Professor

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Cities are densifying at a rapid rate and, accordingly, are constructing high-rise buildings to accommodate more people. The aim of this dissertation was to quantify the physiological and psychological impacts of being in the presence of high-rise buildings. Study 1, which used computer-generated environments and immersive virtual reality, demonstrated that environments populated by high-rise buildings were rated as more oppressive and less open than environments populated by low-rise buildings. In Study 2a, using similar measures, the effects of high-rise buildings a real-world setting in Central London were examined, finding that people rated the high-rise building to be less open and rated themselves to be less happy when exposed to them, as compared to being exposed to the low-rise building. In Study 2b, 360-degree video of the same setting was used in Study 2a and which participants were exposed to using a head mounted device. Participants rated the high-rise building environment to be less open, less friendly and rated themselves to feel less happy and have less sense of control, as compared to low-rise buildings. In Study 3, 360-degree photos were used to examine the effect of distance from high-rise buildings on valence, arousal, sense of control, and openness ratings. Results from Study 3b indicated people were happier, calmer and had a greater sense of control, the further they were from the high-rise. Study 4 examined how exposure to multiple high-rise buildings affected electrodermal activity and valence, arousal, sense of control, and openness. Exposure to high-rise buildings yielded higher electrodermal activity. Taken together, these experiments suggest that exposure to high-rise buildings can have a negative impact on cognition, affect, and physiology. Furthermore, these experiments provide an array of methodologies that can be used to understand the psychological impacts of urban design, a topic which warrants further inquiry as our world continues to urbanize.

Acknowledgements

I would like to thank my supervisor, Dr. Colin Ellard, for the opportunity and mentorship he provided. Colin, thank you for taking a chance on me, someone with no background in psychology let alone cognitive neuroscience, and for providing me with the resources and guidance to help me grow into a scientist. The work we do pushes boundaries; the reason I've been able to do the transdisciplinary research that makes up this dissertation is because of the path you have pushed forward. I admire your willingness to try new things and challenge conventions; I will carry that energy with me as I move forward in my career. I aspire to one day be a supervisor like you: someone who treats their students with compassion and encourages risk taking and out-of-the-box thinking.

I would also like to thank my committee members, Dr. Mike Dixon and Dr. Roxane Itier for the support and advice you provided; I appreciate the excitement you expressed at my weird ideas and your encouragement to persevere when I hit hiccups. I couldn't have asked for a better committee. Thank you to my labmates in the Ellard Lab for your support. Your feedback on my experiments and your friendship were vital to my PhD experience. My RAs, Brandy Murovec, Ali Eskandari, Peri Fedor and Sarah Tang: none of this would have been possible without you. My studies involved many participants, finicky technology, and tight deadlines which you all flawlessly worked around. Thank you as well to the department faculty and admin staff who created a supportive environment for learning.

I am indebted to Dr. Hugo Spiers who welcomed me into his lab at UCL for two visiting fellowships, one cut short by the pandemic. The research we did together comprises Chapter 3 of this dissertation. Hugo, I greatly appreciate the time you made for me, despite having a very busy lab and all of the other professorial responsibilities. I deeply value your mentorship. I also want to extend a thank you to the staff at Goodenough College and the International Lutheran Student Centre in London; you provided an enriching home while I did my research at UCL. A sincere thank you to the Social Sciences and Humanities Research Council for funding my PhD; the Vanier Canada Graduate Scholarship allowed me to comfortably conduct my research while also engaging in my passion for community outreach.

Thank you to my friends, new and old. I'm so grateful this PhD provided the opportunity to travel, meet amazing people, and foster relationships (#saltyjacks).

Sean, there's so much to say, but I'm excited to help support you in your PhD journey. Buckle up, my friend!

I'd planned to write my dissertation while in London, but then the pandemic happened and I had to abruptly fly back to Canada and quickly find a place to live. My sister Rinita and her partner Carson generously took me in, set me up with a desk, and made sure I took breaks from dissertation writing to eat healthy food and go for walks with a beautiful dog named Eugene. I wrote the entirety of my dissertation in their home. Rin, you've supported me in so many ways during this dissertation, but you and Carson inviting me into your home was on another level. You three helped me stay grounded during a tumultuous time in my life. I'm so grateful for you.

Last, but certainly not least, I want to thank my parents, Asit and Swapna Mazumder. Mom and Dad: this wouldn't have been possible without you. As a child you both exposed me to different ideas which without a doubt inspired how I view the world and shaped my research interests. You endured immense struggles and worked tirelessly to provide me with opportunities to grow and learn, and I hope that I've done you justice. I've taken a winding path to where I am today, and you never questioned me. You just supported me. And that's all a son could ask for. I love you. This dissertation is dedicated to you.

Table of Contents

List of Figures

CHAPTER I: Introduction

"It is my conviction that there is within the human individual a sense of relatedness to their total environment, that this relatedness is one of the transcendentally important facts of human living, and that if he tries to ignore its importance to himself, he does so at peril to his psychological well-being." - Searles, (1961, p. 31)

Canada is a largely urbanized nation - 81% of Canadians live in cities (Statistics Canada, 2015). Globally, 54% of the world's population currently lives in urban centres; that number is expected to be 68% by the year 2050 (UN, 2015). There can be many benefits to living in urban centres. Cities are complex environments that function as centres of commerce and hubs for creativity (Bettencourt & West, 2010). They bring diverse peoples together to co-create vibrant places of living. Despite the benefits, there are also risks involved in living in a city. Urban dwellers have been found to be at higher risks of non-communicable chronic diseases, which have been attributable to environmental stressors (Black et al, 2011). For example, respiratory conditions and obesity appear to have higher incidences in cities as opposed to rural areas (Jackson, 2003). In response to findings like this, urban planners and designers have begun to look at the effects of the built environment on physical health. Heath et al. (2006) found sufficient evidence that urban design practices at both street scale and community level were effective in addressing physical health needs. But what about mental health? How does the built environment impact mental health, and how can the built environment be used to promote wellbeing?

Mental health is a topic of growing concern. One in five Canadians experiences a mental health issue (CAMH, 2012). Furthermore, it is estimated that the economic burden of mental illness in Canada is approximately $51 billion annually (CAMH, 2012). Considering the financial and public health implications, it would be prudent to better understand how the urban built environment impacts mental health. Peen et al (2009) conducted a review examining rates of mental illness in rural and urban settings in which they found that urban dwellers had a higher risk of developing mental illness. In explaining this phenomenon, they cite the "breeder theory" which suggests that the environmental influences of living in a city are linked to higher rates of mental illness – one of the key influences being urban stress. McEwen (1998) suggests that there are many aspects of everyday life that can be stress inducing, and that problems can arise when we are chronically exposed to these elements. The urban environment can be chaotic, and daily stressors can come from a number sources – but is there a connection to the built environment?

A literature review by Wandersman and Nation (1998) cites the built environment as an environmental stressor in cities, however their review mentioned very little about how specifically the built environment is linked to mental health. As it stands, there has been much speculation as to the link between the urban built environment and mental health. Considering the rate of urbanization as well as the incidences of mental illness in cities, it is important to understand this connection. As more people move into cities, urban planners and policy makers must be equipped with the information needed to ensure cities support mental health as opposed to cause mental illness.

Does the way a city looks, or rather, how it is perceived, have implications for mental health? Gao et al (2016) found that the aesthetics of a neighbourhood were associated with higher mental well-being. However, they varied in their description of aesthetics. In looking at the relationship between the built environment and alcohol consumption Bernstein et al (2007), measured the built environment of neighbourhoods in New York by assessing the condition, i.e percentage of buildings that were in dilapidated or deteriorating condition. They found that people living in neighbourhoods characterized by “poor” built environments were 150% more likely to report alcoholism than people living in neighbourhoods characterized by “good” built environments, after controlling for individual characteristics. That they obtained these results while controlling for individual characteristics would suggest that the poor built environment was implicated in the increased alcohol consumption. Bernstein (2007) cites the “tension reduction” hypothesis, stating that inhabitants drink alcohol to cope with the stress of poor built environments. Relatedly, Beil and Hanes (2013) measured the built environment on an ordinal scale which ranged from “very natural”, - a space with an abundance of greenery and minimal human influence, to “very built”, - a space that was dominated by human influence with minimal natural greenery. They found that being exposed to “very built environments” increased stress levels in their participants as measured by stress scales as well as salivary amylase – a physiological indicator of stress. Another study, by Galea et al (2005) found that residents who lived in a neighbourhood with a poor-quality built environment experienced higher rates of depression than those who lived in areas with higher quality built environments. They suggested three possible, and not necessarily mutually exclusive, explanations: (1) psychosocial stress: living in poor quality neighbourhoods is associated with psychological distress which in turn places people at higher risks for depression, (2) concentrated disadvantage: poor built environment is associated with other qualities of the neighbourhood that contribute to poor mental health and (3) social drift: people with poor mental health are more likely to drift to neighbourhoods with poor built environments. The psychosocial stress explanation seems to fit well with Bernstein et al’s (2007) tension reduction hypothesis. Furthermore, Peen (2009) discusses the social drift theory of poor urban mental health in his paper exploring the higher rates of mental illness morbidity in cities, but also suggests the "breeder theory" which posits that living in a city exposes people to higher levels of stress which in turn result in higher rates of mental illness as compared to rural areas. Taking the breeder theory into account, what about urban living is more stressful, particularly as it pertains to the built environment? Population-based research has shown that living in cities has impacts on an individual's mental health, although the mechanisms are still not clearly understood (Evans, 2003). Lederbogen et al (2010) conducted a fascinating study that showed that living in a city increased activity in parts of the brain associated with regulation of stress, however they did not explain the specific mechanisms. The urban environment, which can be a very diverse sensory experience, has been shown to affect an individual's cognition and affect state (Negami et al, 2019). Urban stressors can include what *happens* in the city (i.e noise, crowding, social connection), but also what the city *is* (street design, architecture, green space); these two factors are inseparable. Environmental stressors can add to each other, interact, and also depend on the person experiencing them (Lazarus, 1993); this is the challenge of environmental psychological research. In order to understand the complex interaction of environmental stressors in an urban environment, it is necessary to examine a specific environmental stressor. Therefore, the intention of this thesis is to examine deeply the mechanistic psychological impact of one aspect of the urban built environment. One increasingly characterizing feature of cities is the high-rise building. High-rise buildings are being built in response to increasingly limited land use (Ali & Al-Kodmany, 2012) as well as globalized business interests (Parker, 2015). In 2018, 143 skyscrapers were built, at an average height of 247 meters (CTBUH, 2018). Considering their increasing prevalence in our cities, and the constant exposure to them in urban environments, it would be prudent to better understand how they influence our psychological state. Exposure to high-rise buildings can be considered to be an ambient stressor. Campbell (1981) proposes ambient stressors have 5 main characteristics: they are perceptible, chronic, non-urgent, intractable and have a negative tone. The word "ambient" is used to highlight the fact that these stressors are often in the background and not at the forefront of our awareness. Ambient stressors can, over the long term, have negative impacts on wellbeing (Campbell,1981). In discussing perceptibility, Campbell suggests that ambient stressors are typically perceivable, but may not be noticed, but that noticing them may have no bearing on their deleterious effects. Chronicity refers to the extent that the stressor is present; for the urban dweller, high-rise buildings can be a constant feature of the environments they occupy. Non-urgency refers to the immediate threat posed by a stressor; high-rise buildings, at least psychologically, do not impose a tangible threat. Intractibility, which is closely related to non-urgency, entails that the individual can not moderate the experience of the ambient stressor by cognitive reframing . The urban dweller can't do much about exposure to high-rise buildings, other than leave settings where they are present, which may not be tenable in most cities. Lastly, negative tone refers to the affective quality of the ambient stressor which has a negative psychological influence on the experiencer. This last feature is what is primarily of interest in this dissertation; how does exposure to high-rise buildings influence our affective state? To answer this question, we must first situate it within a theoretical framework.

Affective Responses to the Built Environment

In his collection of books, *De Architura*, Vitruvius, a Roman architect, philosopher and engineer, suggested three core principles for architecture: structural integrity, function, and attractiveness (Morgan, 1914). Throughout his treatise, he emphasizes the importance of beauty and aesthetics. The construction of the built environment is not just a utilitarian endeavour; how it looks and how it makes us feel has importance. In discussing temple construction, he alludes to the psychological considerations of architecture, stating, "when the height is great, its strength is sucked out of it, and it conveys to the mind only a confused estimate of the dimensions" (Morgan, 1914, Book 3). Vitruvius was one of the first architects to consider the science of what today could be called environmental psychology. In the first issue of the Journal of Environmental Psychology, Canter and Craik (1981, p. 2) define environmental psychology as the "area of psychology which brings into conjunction and analyzes the transactions and interrelationships of human experiences and actions with pertinent aspects of the socio-physical surroundings." This dissertation in particular is interested in the physical environment, and accordingly aligned with the subfield of environmental aesthetics, which Aatov (1998) states, "attempts to explain a psychological phenomenon by investigating how an environment's visual qualities and attributes affect responses by individuals, groups, or the general public" (p. 240). In his book, *Mind and Emotion* Mandler (1975), suggests that an individual's affective response to an external event is informed by their cognitive appraisal of the event, their previous experiences with similar events, and their autonomic nervous system response. Purcell builds on Mandler's work and proposes the Schema Theory of Environmental Perception (1986), where he contends that the affective response to the built environment is informed by previous experience; the affective response is an indicator of the discrepancy between the default values or "prototype" and what is currently being experienced. In discussing environmental psychological research on urban environments, Proshansky (1976), who is considered to be one of the founders of environmental psychology, suggests that there two systems at play when an individual responds to their environment, the psychological response system in which an individual is aware of their response, and the behaviour response system of which the individual is not consciously aware.

He goes on to argue that these systems have implications on how we go about measuring the different responses; subjective self-report would not suffice in measuring the unconscious response to the built environment. Whether someone is conscious of how an environment affects them, does not have bearing on the fact that it still *does* affect them, which again highlights the importance of assessing ambient stressors. Accordingly, physiological responses must be measured. Nasar (1994), a collaborator of Purcell (1992), takes the cognitive appraisal, affect and physiology into account in his Probabilistic Model of Aesthetic Response. The Probabilistic Model of Aesthetic Response (Figure 1) accounts for the complexity of environmental perception, acknowledging the interaction between affect, perception, and cognition to produce an affective response, which can be measured through using an affect measure, physiological indicator, and behaviour. Nasar (1992) identifies building scale, height included, as an attribute that can influence an individual's affective state.

Exposure to High-Rise Buildings

The majority of the scant literature on the aesthetic impact of high-rise buildings has focused on the skyline, or how high-rise buildings are viewed from a considerable distance (Sev, 2010). Very few have examined how they may be perceived in close proximity. Lindal and Hartig (2013) found that building height was negatively correlated with restoration likelihood; suggesting that someone in a state of stress is less likely to feel restored when in the presence of high-rise buildings. It has also been suggested that being in the presence of high-rise buildings causes behavioural freezing (Joye & Dewitte, 2016 p. 123), who theorize that high-rise buildings "create an oppressive and threatening atmosphere, which might trigger defensive responses." This issue has been formally explored, and it has been shown that high-rise buildings cause feelings of oppressiveness. (Zarghami et al. 2019; Asgarzadeh, Luska, Kogab and Hirate, 2012;

Asgarzadeh et al. 2014). It is suggested that the feelings of oppressiveness relate to the emotions engendered by the invasion of personal space and that oppressiveness can evoke a sense of crowding that can cause feelings of anxiety and stress (Asgarzadeh, Luska, Kogab and Hirate, 2012).

Ecologically Valid Environments

As mentioned earlier, a challenge of environmental psychology is the methodology used to examine the effects of an environment. Real-world research can provide insights into the impact of an environment, however, it can be difficult to control for specific variables. In-lab studies afford greater empirical control, but prompts valid concerns about ecological validity. Bronfenbrenner (1977, p. 140) described ecological validity as "the extent to which the environment experienced by the subjects in a scientific investigation has the properties it is supposed or assumed to have by the experimenter." Taking this definition into account, it is important to consider what exactly an environment is; does it refer to the space an individual is in or the imagination and conceptualization of that space? This is an important question to consider when assessing the existing research done on the psychological impacts of the built environment. Furthermore, research that informs policy and practices that ultimately shapes the world we live in should endeavour to be ecologically valid (Schmuckler, 2001). In reference to the considerations needed in conducting lab-based research, Baddeley (1989) speaks of the "tension between the need for control and the need to preserve the essence of the phenomenon under investigation" (p. 104). Experimental control allows confidence in the effects of the variables measured, whereas regularity allows confidence in the generalizability of the results (Rubin, 1989). It is a fine balance to obtain in psychological research, particularly environmental psychological research, which seeks to understand how an individual's environment affects an individual. Invoking Bronfenbrenner's definition of ecological validity, I would contend that environmental psychology should establish high standards, considering the emphasis in this area of research on the environment. In an attempt to maintain some experimental control while evaluating the influence of the environment, environmental psychologists have used a number of methods to simulate the environment, including pictures, drawings, video, physical recreations, and computer simulations (Rohrman and Bishop, 2002). The studies exploring the psychological impact of exposure to tall buildings have all used two dimensional pictures or computer-generated drawings (Lindal & Hartig, 2013; Zarghami et al. 2019; Asgarzadeh, Luska, Kogab and Hirate, 2012; Asgarzadeh et al. 2014; Joye & Dewitte, 2016). Although Stamps (2010) suggests that 2D renderings and pictures are as effective as more realistic simulations, I believe that given that the mass and size of buildings is what has been implicated in having a psychological effect on people, pictures, real or manufactured, are likely not adequate in evoking the experience I am interested in studying. To understand how the scale of a building, particularly its height, affects people, we must expose them to that scale. Accordingly, this body of research used both immersive virtual reality and real-world settings to expose people to high-rise buildings. Following Nasar's (1994) Probabilistic Model of Aesthetics, the subjective variables examined in this thesis will include cognitive, affective, and physiological. Figure 1, found on the next page, graphically displays the results of a recent systematic review (Karakas & Yildiz, 2020) conducted on research that uses a psychophysiological approach to examining the impacts of the built environment. As technology advances, this small but burgeoning area of research continues to diversify in its methodological approach. This dissertation, which began well before this article was published, spans all the categories of settings and types of methods identified.

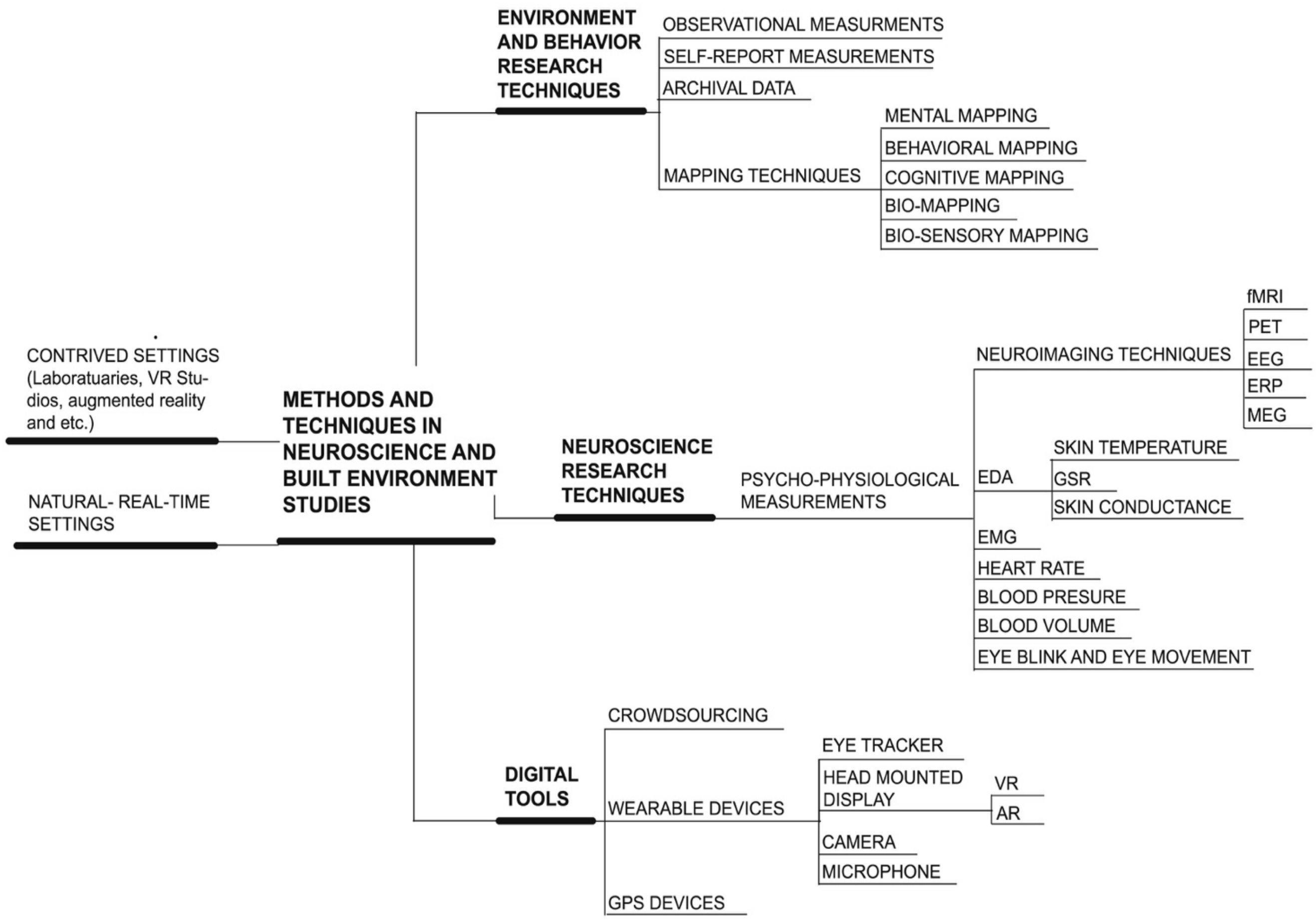

Figure 1. Overview of methodologies used to examine the relationship between neuroscience and the built environments (Karakas & Yildiz, 2020).

The research was conducted in both natural-real-time and contrived settings, applied environment and behaviour research techniques (self-report measurements), implemented neuroscientific research techniques (electrodermal activity), and used digital tools (virtual reality presented in head mounted displays). Our approach ensures a holistic understanding of the phenomena of interest.

In Study 1, I wanted to use a high level of control over building height, so we built a virtual city in Unity (a computer game development program) which I then placed participants in using a head mounted device (HMD). Cognitive appraisal measures, affect measures and electrodermal activity were used to assess participants' responses to the environment. In deference to the limitations of a computer-generated urban environment, in Study 2a I chose to measure people's responses to high-rise buildings in the real world, where I again used cognitive appraisal measures, affect measures and electrodermal activity. In conducting Study 2a, I became acquainted with the challenges of conducting real world research, such as reduced experimental control as well organizational challenges. Therefore, in Study 2b, I used 360-degree video of the exact settings in Study 2b and exposed participants to it using an HMD, while maintaining all other procedures used in Study 2a. Study 2b allowed me to better standardize the stimuli to which participants were exposed. Specifically, all participants were exposed to the exact same set of built stimuli, cars, pedestrians and street view, as opposed to Study 2a where many of the stimuli were in constant flux, as one would expect in a real-world setting. Study 2b also allowed me to run significantly more participants. Studies 1, 2a and 2b all involved maintaining a static distance from buildings; therefore, in Study 3, I was interested in manipulating proximity to a high-rise building to examine the cognitive, affective and physiological effects of distance on perceivers. Here our high-rise exemplar was, the Toronto Dominion Centre, in Downtown Toronto. For this study, I used an HMD to expose participants to 360-degree photos, which allowed me to edit out other buildings and also remove the presence of people from the scenes, which I believed would be a confound. Lastly, in Study 4, I employed a methodology that exposed participants to multiple 360-degree videos of high-rise buildings, using an HMD, to ensure that the effects of building height on the cognitive, affective and physiological measures observed aren't driven by a specific building, and also to use high fidelity measures of electrodermal activity.

Taken together, these studies endeavoured to provide a complete picture of the impacts of exposure to high-rise buildings, and also to present a generalizable, ecologically valid, methodology to examine the psychological impacts of the built environment.

CHAPTER 2: Using Manufactured Urban Environments In Virtual Reality[1]

In Chapter 2, I present the first study of the dissertation, which explores how being in the presence of computer-generated models of high-rise buildings in a virtual urban environment can influence an individual's affective, cognitive and physiological state

Previous studies that suggest high-rise buildings can have a negative psychological impact used static pictures (Lindal & Hartig, 2013; Zarghami et al. 2019; Asgarzadeh, Luska, Kogab and Hirate, 2012; Asgarzadeh et al. 2014; Joye & Dewitte, 2016). Exposure to high-rise buildings is suggested to cause feelings of oppressiveness, which has been described to be akin to an invasion of space (Asgarzadeh et al., 2012, 2014; Zarghami et al., 2019). While those insights are an interesting first step, pictures cannot evoke the invasive, oppressive feeling that is reported. Higuera-Trujillo, Moldonado and Millan (2017) examined the validity of the use of photos, panoramic photos and virtual environments to simulate real environments. They found virtual reality environments were the most realistic, as measured by physiological responses. Computer-generated virtual reality environments have been previously used in a wide variety of applications including understanding the restorative effects of nature (Valtchanov, Barton & Ellard, 2010), examining gait patterns (Ehgoetz Martens, Ellard & Almeida, 2015), and assessing wayfinding in virtual urban environments (Valtchanov, Barton, & Ellard, 2014). In a review of the use of virtual reality in clinical, affective, and social neuroscience, Parsons (2015) states, "given that virtual environments allow for precise presentation and control of dynamic perceptual stimuli, they can provide ecologically valid assessments that combine the control and rigor of laboratory measures with emotionally engaging background narratives to enhance assessment of cognition, affect, and social interactions" (p.14). Accordingly, in an attempt to

[1] A version of this chapter was submitted to the Journal of Architectural and Planning Research for publication in May 2020

ensure ecological validity, while maintaining control over the settings, we used Unity, a game development software, to develop virtual urban environments populated with low-rise and high-rise buildings which I then exposed participants to using an HMD. Like Asgarzadeh, Luska, Kogab and Hirate (2012) I was also interested in learning how urban foliage mitigated the stress effects of high-rise buildings. Previous research suggests that exposure to urban greenspace can mitigate stress (Tyrvainen et al, 2014). I used electrodermal activity as an indicator of the level of stress of participants. Electrodermal activity has been shown to be a reliable measure of sympathetic nervous system activity, and accordingly can be used to examine the stress response (Dawson et al, 2011). Electrodermal level is typically used, as opposed to specific skin conductance responses, when assessing the effects of environmental exposure (Dawson, 2011). To explore participants cognitive appraisals, I also used subjective measures similar to those used by Asgarzadeh, Luska, Kogab and Hirate (2012), who examined the impact of high-rise buildings on oppressiveness. Furthermore, the Implicit Positive and Negative Affect Test was used (Quirin, Kazen & Kuhl, 2009) to measure participant mood. A problem with explicit affect measures can be that participants might not find it difficult to guess the intentions of the experimenter or to discount biases against a particular kind of design based on hearsay or on popular media accounts of the value of certain kinds of designs. An implicit affect measure was chosen as opposed to an explicit measure to better access an individual's true emotional state as influenced by their surroundings.

I hypothesized that being in the presence of high-rise buildings, as compared to low-rise buildings, would yield higher oppressiveness ratings, lower openness ratings, higher disturbingness ratings, lower openness satisfaction ratings, lower friendliness ratings, higher negative affect ratings, lower positive affect ratings, and higher stress, as measured by electrodermal activity. I also expected that the presence of trees would lower the magnitude of participants' responses in all of the aforementioned measures.

Materials and Methods

Participants

A total of 130 undergraduate students (73 female, Average Age = 20.22 years) were recruited from the University of Waterloo undergraduate research pool between September 2016 and August 2017. Students participated in order to receive course credit in psychology courses. This study received ethical approval from the University of Waterloo's Office of Research Ethics (ORE #21656, approved 22 August 2016).

Apparatus

nVis

The immersive virtual reality environments were presented using an nVisor SX60 virtual reality headset nVis (Reston, Virginia). The device features a resolution of 1280X1080 pixels with a diagonal field of view of 90-60 degrees. The device weighs approximately 1 kg and features two adjustable straps to ensure a tight and comfortable fit.

Shimmer

The Shimmer3 GSR+ Unit (Dublin, Ireland) sensor is a wearable device that features two small sensors which measure electrodermal activity on the ring and middle fingers. These wired sensors attach to the Shimmer device and velcro straps hold the sensors to the fingers. The Shimmer GSR+ Unit sensor measures electrodermal activity in microsiemens.

Environments

Participants were randomly assigned to one of four immersive virtual environments (Figure 2) that were designed using Unity: (1) low-rise buildings, (2) high-rise buildings, (3) low-rise buildings with trees present, (4) high-rise buildings with trees present. These settings were informed by Asgarzadeh et al's (2012) study, which examined participant oppressiveness ratings to buildings of varying heights with or without trees present. The low-rise buildings were 3 storeys high. The high-rise building environments were 40 storeys.[2]

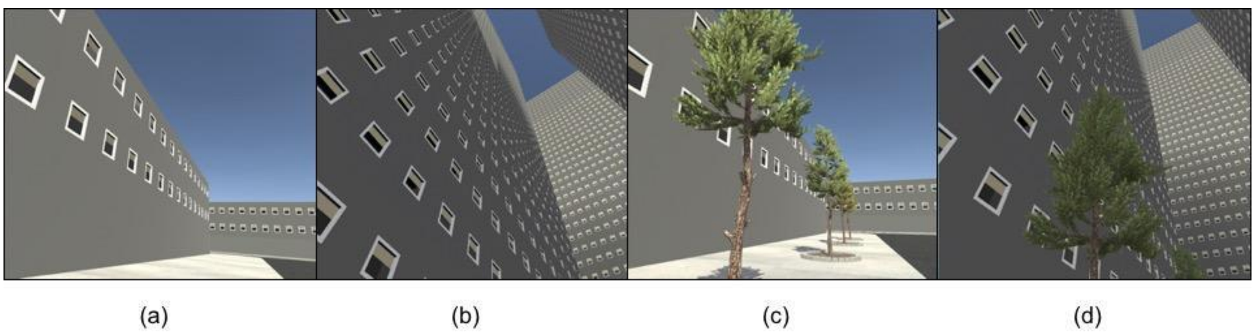

Figure 2. Immersive virtual environments participants were exposed to: (a) low-rise building, (b) tall building, (c) low-rise building with trees, (d) tall building with trees.

Measures

Affect Measure

The Implicit Positive and Negative Affect Test (IPANAT) (Quirin, Kazen & Kuhl, 2009) is an instrument that measures an individual's positive and negative affect indirectly. Participants are asked to rate gibberish words (SAFME, VIKES, TUNBA, TALEP, BELNI, SUKOV) on the extent to which they convey positive emotion (happy, energetic, cheerful) and negative emotion (helpless, tense, inhibited). These words are rated on a 4-point scale (1 = doesn't fit at all, 2 = fits

[2] In 2015, GL Hearn and New London Architecture released a report indicating that the average height of tall buildings in construction in London were 30 storeys tall (New London Architecture, 2015)

somewhat, 3 = fits quite well, 4 = fits very well). Scores are derived by first averaging single word ratings from all gibberish words (i.e happy ratings for all six gibberish words are averaged). Then, the ratings for positive emotion words are averaged to produce a positive affect score and the ratings for negative emotion words are averaged to produce a negative affect score.

Physiological Measure

Electrodermal activity, also known as skin conductance, is the measure of the rate of sweat gland response. It is generally considered to be a reliable index of sympathetic autonomic nervous system activity and indexes roughly with the concept of stress. Skin conductance level is used, as opposed to skin conductance responses, when assessing the effects of environmental exposure (Dawson, 2011). In this study, electrodermal activity was measured using a wearable device (Shimmer). A two-minute baseline reading was taken prior to exposing the participants to the immersive virtual environments to (a) ensure they were at rest prior to exposure and (b) have a baseline to compare values obtained during exposure. To account for individual differences in electrodermal activity in a between-subject study design, participants' recordings were z-transformed using the mean and standard deviation obtained from their two-minute baseline reading. The z-transformed skin conductance scores corresponding to the 5-minute exposure were then averaged and divided into 1-minute intervals to produce five electrodermal activity values per participant.

Cognitive Appraisal

The subjective cognitive appraisal measures used by Asgarzadeh, Luska, Kogab and Hirate (2012) were adapted for use in this study. Participants were asked to answer the following questions in relation to the immersive environments they were placed in on a scale of 1-7 (not at all - very): (1) How oppressed did you feel? (2) How disturbing was this feeling of oppressiveness? (3) How open did you perceive the setting to be? (4) How satisfied were you with the openness? and (5) How friendly was the setting?

Procedure

This was a between-subjects design in which participants were exposed to one of four immersive virtual environments (Figure 3). Deception was used in this study to avoid priming participants to evoke an emotional response as measured by the Shimmer and to avoid priming responses on the IPANAT and Oppressiveness Scales. Participants were informed that this study was comparing experiences of virtual environments to that of real environments. They were also told that they would have to sketch what they saw in the virtual environment following their five-minute exposure to it. This deception was used to ensure they thoroughly attended visually to their environment.

Participants were then fitted with the Shimmer on their non-dominant hand and asked to sit quietly for two minutes to capture a baseline electrodermal activity reading. They were then placed in one of four immersive virtual environments using the nVis headset. The immersive virtual environments were randomly selected using a preprogrammed algorithm. Participants sat on a chair which, in the model, was aligned with a virtual city bench, for five minutes and asked to observe their surroundings. The nVis headset was then taken off and participants were asked to complete the IPANAT instrument followed by the Oppressiveness Rating Scales on a desktop computer.

Figure 3. Diagram of experimental procedure.

Results

Exclusions

Due to a malfunction with the Shimmer data collection software, 30 data files were empty and unusable for analysis of the electrodermal activity variable and were therefore excluded from the ANOVA analysis. These thirty participants were replaced, with the new participants pseudo randomized to ensure that there were 25 electrodermal activity recordings for each of the four conditions.

ANOVAS

One-way between subjects ANOVAS were performed to examine the effects of building height and the presence of trees on the variables of oppressiveness, openness, disturbingness, friendliness, openness satisfaction, and negative affect and positive effect. In the service of brevity only statistically significant differences are reported. High-rise buildings were rated as being significantly more oppressive ($M = 2.85$, $SD = 2.13$) than low-rise buildings, (Figure 4), $F(1,126) = 5.21$, $p = .024$, $\eta_p^2 = 0.04$. As predicted, there was also a significant main effect of building height on openness ratings ($M = 3.18$, $SD = 1.99$) $F(1,126) = 5.21$ $p = 0.024$, $\eta_p^2 = 0.04$ (Figure 5). Contrary to Asgarzadeh et al's (2012) findings, I found that there was no significant effect of the presence of trees on any of the measures, nor were there any interactions. There was no effect of building height or presence of trees on disturbingness, friendliness, openness satisfaction. There was also no effect of building height or vegetation on positive or negative affect as measured with the IPANAT.

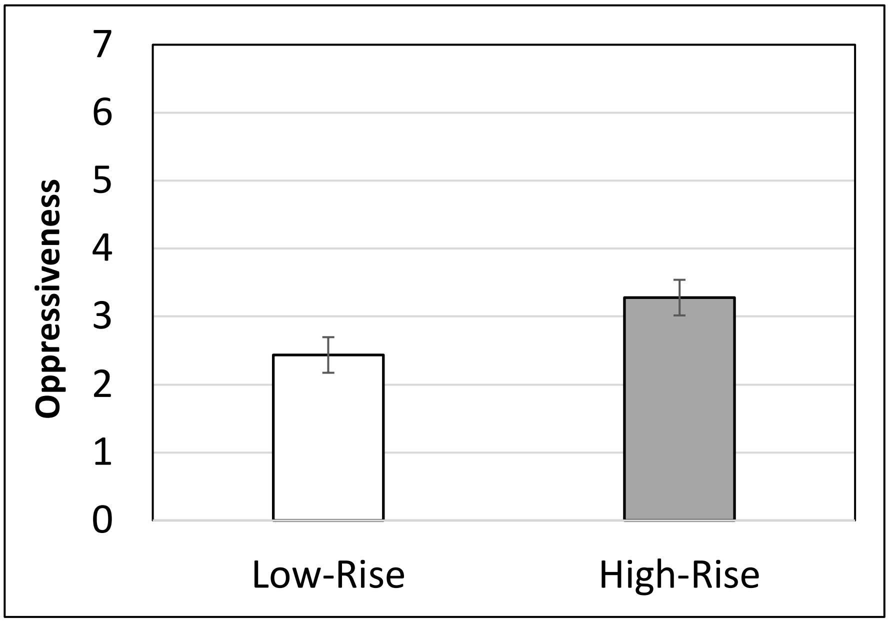

Figure 4. Bar graph showing the influence of building height on oppressiveness ratings. Error bars represent ± 1 SEM.

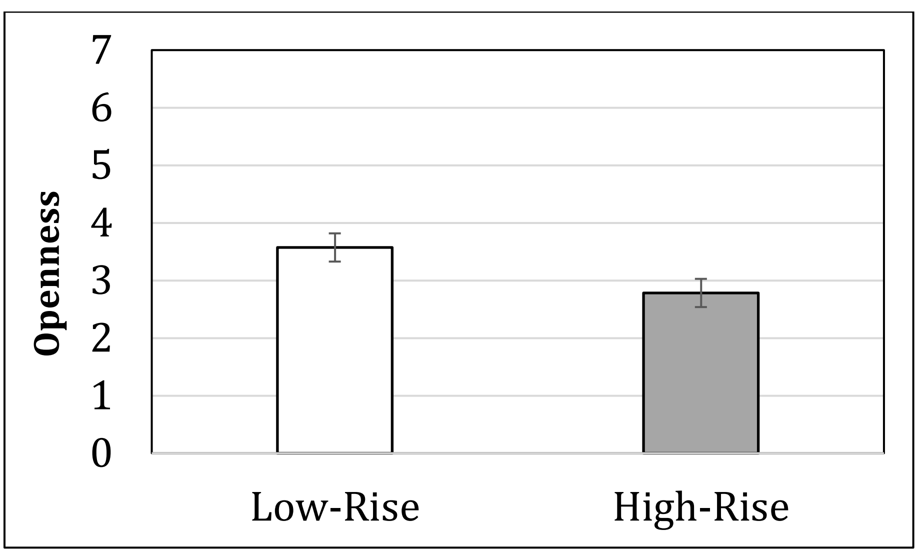

Figure 5. Bar graph showing the influence of building height on openness ratings. Error bars represent ± 1 SEM.

Repeated Measures

A one-way repeated measures ANOVA was performed on the 1-minute intervals of z-scored electrodermal activity values, using building height and the presence of trees as the independent variables. There was a significant effect of height on electrodermal activity (Figure 3) $F(4,54) = 3.38$, $p = .01$, $\eta_p^2 = .034$ (Figure 6). Pairwise comparisons were made (Figure 4) for each of the 1 minute intervals, and there was a trending effect in the 4th minute $t(98) = -1.71$, $p = .09$ and a statistically significant difference at the 5th minute, $t(98) = -2.40$, $p = .018$.

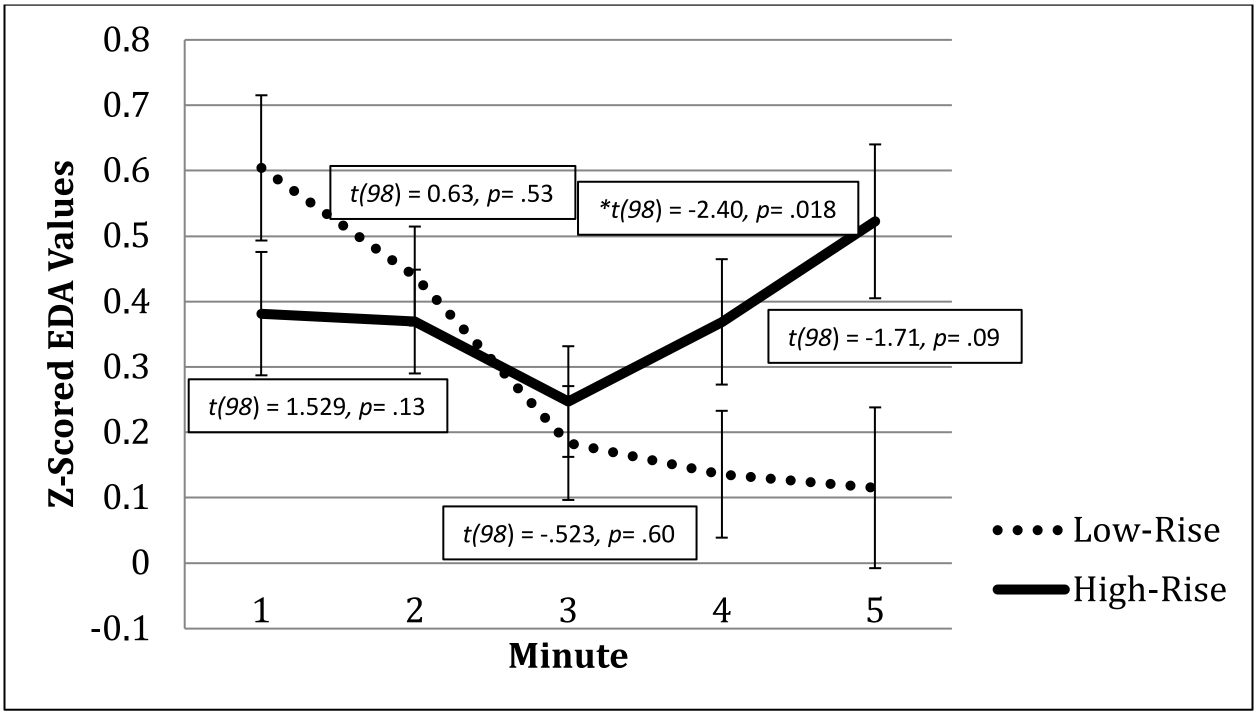

Figure 6. Line chart demonstrating the effect of building height on electrodermal activity. Error bars represent ± 1 SEM. Pairwise comparisons are provided for each minute. Significant difference denoted with asterisk.

Discussion

This study demonstrated that people rated virtual environments containing high-rise buildings as more oppressive and less open than virtual environments containing low-rise buildings. I also found that participants experienced higher arousal, as measured by electrodermal activity in the high-rise building environment than they did in the low-rise building environment. I propose that electrodermal activity is a viable tool that can be used to quantify the physiological and psychological impacts of oppressiveness.

Our findings align with those of Asgarzadeh, Luska, Kogab and Hirate (2012), who, using pictures, demonstrated that high-rise buildings were considered to be more oppressive and less open. While stress was not explicitly measured by Asgarzadeh, Luska, Kogab and Hirate (2012), it was suggested that oppressiveness can cause a subtle, chronic stress. Our electrodermal activity findings can potentially corroborate these findings, if we were to accept that arousal levels are indicators of stress. Our pairwise analysis shows that the greatest effect on electrodermal activity occurred towards the end of the five-minute exposure; this could suggest that the physiological impacts of oppressive environments are ones that build gradually over time. Asgarzadeh, Luska, Kogab and Hirate (2012) suggest that high-rise buildings can cause feelings of crowding, in the same way that researchers in proxemics have shown that invasions of personal space by others can produce this effect. Nicosia, Hyman, Karlin, Estein, and Aiello (1979) found that people who felt crowded in a small room had higher skin conductance levels; there is a possibility that being crowded by buildings can cause a similar response.

Our data also supports Lindal and Hartig's (2013) findings that high-rise building environments are less restorative than low-rise building environments; their study involved having participants rate pictures of urban scenes on different elements, including restoration likelihood. Lindal and Hartig (2013, p. 29) suggest that restoration "involves the renewal of physical, psychological, and/or social resources diminished in ongoing efforts to meet everyday demands." A heightened autonomic response in the high-rise building environment, as measured by the higher electrodermal activity, would suggest that this environment is less restorative than the low-rise building environment. High-rise building environments can arguably cause stress; they also can inhibit someone's ability to recover from other stress they experience in their day to day life. Joye and Dewitte (2016), who also used pictures, found that high-rise buildings caused behavioural freezing, which they suggest is caused by the fact that high-rise buildings are threatening. They also found that high-rise buildings can causes feelings of entrapment; this aligns with our finding that high-rise building environments were rated as being less open - or, more enclosed - than low-rise building environments. Stamps (2010) suggests that perceived enclosure is related to diminished feelings of safety; Vartanian et al (2015) found that participants were more likely to avoid enclosed spaces. While I did not measure behavioural freezing, the link between freezing and autonomic sympathetic activation (Lojowska et al., 2015) corroborates our finding that high-rise buildings produce threat responses similar to those seen in the Joye and Dewitte (2016) study.

One limitation of our study is the failure of the IPANAT to capture any effects of high-rise buildings on affect. This could be due to the fact that there was no measurable effect of building height on the emotional state of study participants, or that the responses to the buildings were driven entirely by explicit, conscious affect, perhaps relating to conscious assessments based on previous associations with these styles of urban design. However, given the convergence of the effects of building height on electrodermal activity and oppressiveness ratings, it does not seem plausible that there would be no effect on affect. The IPANAT is an implicit measure; it claims to access an individual's subconscious emotional state (Quirin, Kazen & Kuhl, 2009). There is a possibility that the IPANAT is not sensitive enough to pick up the affective influence of high-rise buildings; in this case I may need to use a more explicit measure of affect, such as the Positive and Negative Affect Schedule or the Self-Assessment Manikin. Furthermore, in a recent review of the literature on the IPANAT and its connection to the autonomic nervous response, Weil, Hernandez, Suslow, and Quirin (2019) suggest that research needs to be done exploring the connection between the IPANAT and electrodermal activity. Furthermore, the Somatic Marker Hypothesis suggests that an emotional experience can elicit a bodily response without an accompanying cognitive component; accordingly, ambient stressors in the urban environment may go unregistered by participants but still have a tangible impact on the body (Damasio, 1996). As methods of assessment of affect are used commonly in environmental psychology, it will be important to follow up on our failure to find effects using the IPANAT even in the clear presence of symptoms of threat responses to our high-rise buildings. Of note, as well, is the length of the IPANAT. At 36 questions, it is an intensive assessment, which may have implications on how well it captures an individual's affect following exposure.

Another concern is the failure to replicate findings that suggest that the presence of trees can mitigate oppressiveness and stress. de Kort, Meijnders, Sponselee, and IJsselsteijn (2006) found that showing participants film of nature scenes had restorative effects, and the level of restorativeness was modulated by the level of immersion. Given that participants were in a fully immersive environment, I should have expected some level of restoration. However, the trees participants were exposed to were low-polygon count virtual trees, and may not truly be representative of actual trees. Valtchanov, Barton and Ellard (2010) did find that virtual trees decreased stress, although participants were exposed to forested settings, and the quality of detail in the landscapes used in their study was considerably higher than in the present work. Work by Valtchanov and Ellard (2015), suggests that the properties of natural images that produce the restorative response depend heavily on the spectrum of spatial frequencies present in an image. Thus in light of their findings, it is possible that the vegetation in our images did not match the optimal spatial frequency power spectrum for generating the restorative response. Related to this is the absence of fractality of the computer-generated trees; fractal patterns, edges and hue are implicated in the restorative qualities of trees (Schertz & Berman, 2014).The absence of an effect in our study may also be due to the density of trees; participants were placed on an urban sidewalk with a few trees in their field of vision as opposed to being placed in a whole forest. In addition, considering that participants in Asgarzadeh et al's (2012) study were shown a static picture, the presence of trees always informed part of their assessment of oppressiveness. Given that immersive virtual reality is a dynamic experience, which varies greatly between participants, participants did not necessarily have to keep the trees in their field of vision during the experiment. While they were encouraged to completely explore their environment, the researchers were not able to control exactly what it was the participants experienced; this is part of the trade-off involved when conducting psychological experiments that employ virtual reality. Lastly, I obtained small to medium effect sizes for the effects of building height on oppressiveness, openness and electrodermal activity. This could be explained by the fact that a simulated urban environment was used. While virtual reality allows high experimental control, such as being able to manipulate building height and remove other stimuli that would be present in a city (such as noise, people, weather), it is still a simulated, manufactured setting. For subsequent studies, I plan on using 360-degree video recordings of locations populated by high-rise buildings. This would provide the immersiveness, but would be more realistic, and a compromise between simulated 3D environments, which may not be strong enough to elicit an affective response, and a field study in the city, which may contain other confounds that can affect the data.

Despite the identified limitations, this research has some lessons for the urban design and architectural industries. Our research suggests that people feel oppressed and are in an aroused state when in the presence of high-rise buildings. Furthermore, they find high-rise building environments to be less open. Should city builders think about the psychological impacts of building upward? From the developer's perspective, building height is determined by the potential for profitability (Barr, 2012). Municipal governments, however, are developing guidelines on how high-rise buildings can affect the wellbeing of people who exist around them, however they focus on how skyscrapers block daylight and create wind tunnels, not necessarily the visual experience of the skyscrapers themselves (City of Toronto, 2013). As cities continue to densify, and as more research is done in this field, it would be prudent for cities should consider the psychological implications of building upward.

CHAPTER 3: Real World and 360-Degree Video[3]

In Study 1, I established that exposure to high-rise buildings had a negative effect on some select cognitive variables, and on physiological measures. While these findings are interesting, the issue of ecological validity is a concern, considering that the first study was conducted using computer-generated environments. Study 2a aimed to bring this research into the real world. In study 2a, I examined how participants responded affectively, physiologically, and cognitively to high-rise buildings in Central London. Participants were brought to a high-rise building and a low-rise building in Central London; their responses to the two buildings were measured using electrodermal activity, the Self-Assessment Manikin (SAM) (Bradley & Lang, 1994), and the same cognitive appraisal measures used in Study 1. Due to the issues with the Implicit Positive and Negative Affect Test (IPANAT) (Quirin, Kazen & Kuhl, 2009) in Study 2a, I opted to use the SAM, an easy to administer and quick assessment of affect that assesses three variables: valence, arousal and dominance (Bradley & Lang, 1994). While dominance is typically used to measure feelings of dominance in social situations, I thought it might also capture feelings of being overwhelmed (and made to feel small) by tall buildings. The SAM uses 3 simple pictorial scales, compared to the IPANAT, which requires the participant to answer 36 questions (Quirin, Kazen & Kuhl, 2009). The ease of use of the SAM is particularly relevant when being administered in real world settings, where a paper and pencil assessment needed to be used. In Study 2b 360-degree video (with audio) was taken of the exact locations used in study 2a. Participants were then exposed to the video using immersive virtual reality in the lab; the same measures from the Study 2a. The intention of Study 2b was to further explore how high-rise buildings can influence feelings of oppressiveness, stress and affect, but also to

[3] A version of this chapter was submitted to the Cities & Health for publication in May 2020

examine whether immersive virtual reality and 360-degree video could be used effectively to elicit similar effects to those found in the real world. Thus 360-degree video presented in an HMD was thought to serve as an attractive compromise between real world settings and computer-generated emulations.

There is particular relevance of this research to London; as more people flock to the city, it is faced with the challenge of accommodating this influx of people. One strategy used to combat outward sprawl is to build upwards. Ali and Kodmany (2012) celebrate tall buildings as a key agent in urban densification, citing the benefits of economic development and land preservation. In 2018, 143 skyscrapers were built, at an average height of 247 meters (CTBUH, 2018). While tall buildings can help concentrate population in a small area, they drastically change the cityscape. Conscious of the implications of a shifting skyline, some have taken issue with this transformation. In an effort to preserve architectural heritage, the City of London has historically been restrictive of allowing tall buildings (Charney, 2007). In 2007, in a response to such concerns, the Greater London Authority established the London View Management Framework, a formalized mandate to ensure vistas and views of historical sites were not obstructed by tall buildings (Appert & Montes, 2015). Despite this framework, the city has continued to build tall buildings rapidly, and most have not been built to accommodate housing, but, rather business. Between 2000 and 2016, thirty-two skyscrapers were built in Central London and it has been suggested that this was driven by foreign corporate interests capitalizing on the plummeting Pound Sterling enabling them to establish a commercial presence in the city (Craggs, 2018). Accordingly, Parker (2013, p. 234) suggests that skyscrapers are “capital made durable.” Regardless of the driving forces, the fact remains that the topography of London’s urban landscape is quickly shifting with the upswell of tall buildings being built. How does their presence impact the experience of the city? This study purported to examine the question of how high-rise buildings in Central London, in the real world and in virtual reality, influence affect, cognition, and physiology. In both studies, I hypothesized that standing in front of a tall building, as compared to standing in front of a short building, would yield higher arousal ratings, higher negative valence ratings, lower dominance ratings, higher oppressiveness ratings, lower openness ratings, higher disturbingness ratings, lower openness satisfaction ratings, lower friendliness ratings, higher negative affect ratings, lower positive affect ratings, and higher stress, as measured by electrodermal activity.

Materials and Methods

Participants

Study 2a

A total of 16 participants (8 female, Average Age = 28.95 years) were recruited from the University College London SONA research pool in August 2018. Participants were paid 10 GBP to participate in the study. This study received ethical approval from the University College London's Office of Research Ethics (#CPB/2013/015).

Study 2b

A total of 121 undergraduate students (83 female, Average Age = 19.62 years) were recruited from the University of Waterloo undergraduate research pool between September 2018 and April 2019. Students participated in order to receive course credit in psychology courses. This study received ethical approval from the University of Waterloo's Office of Research Ethics (ORE #21656, approved 22 August 2016).

Apparatus

HTC Vive

In Study 2b, 360-degree video was presented to participants using a HTC Vive headset (Microsoft, Redmond WA). The device features a resolution of 2160X1200 pixels with a field of view of 110 degrees. The device weighs approximately 555 grams and features three adjustable straps to ensure a tight and comfortable fit. The Vive contains on-board motion tracking so that scenes are updated corresponding to movements of the participant's head.

Measures

Affect Measure

The self-assessment manikin (SAM) (Figure 7) is a pictorial measure that assesses valence, arousal and dominance (sense of control). The SAM was developed in response to the semantic differential model (Mehrabian & Russel, 1974), as it was determined the semantic differential model, at 18 9-point-scale questions, was too cumbersome to use to measure these constructs (Bradley & Lang, 1994). The SAM was intended to measure responses to objects and events, which makes it an appropriate measure to examine the psychological impacts of a building, an object. Participants are instructed to mark the manikin that aligns with how they feel; if they could not choose a manikin, they could mark the space between. A paper pencil method was used for both the real world and virtual reality study.

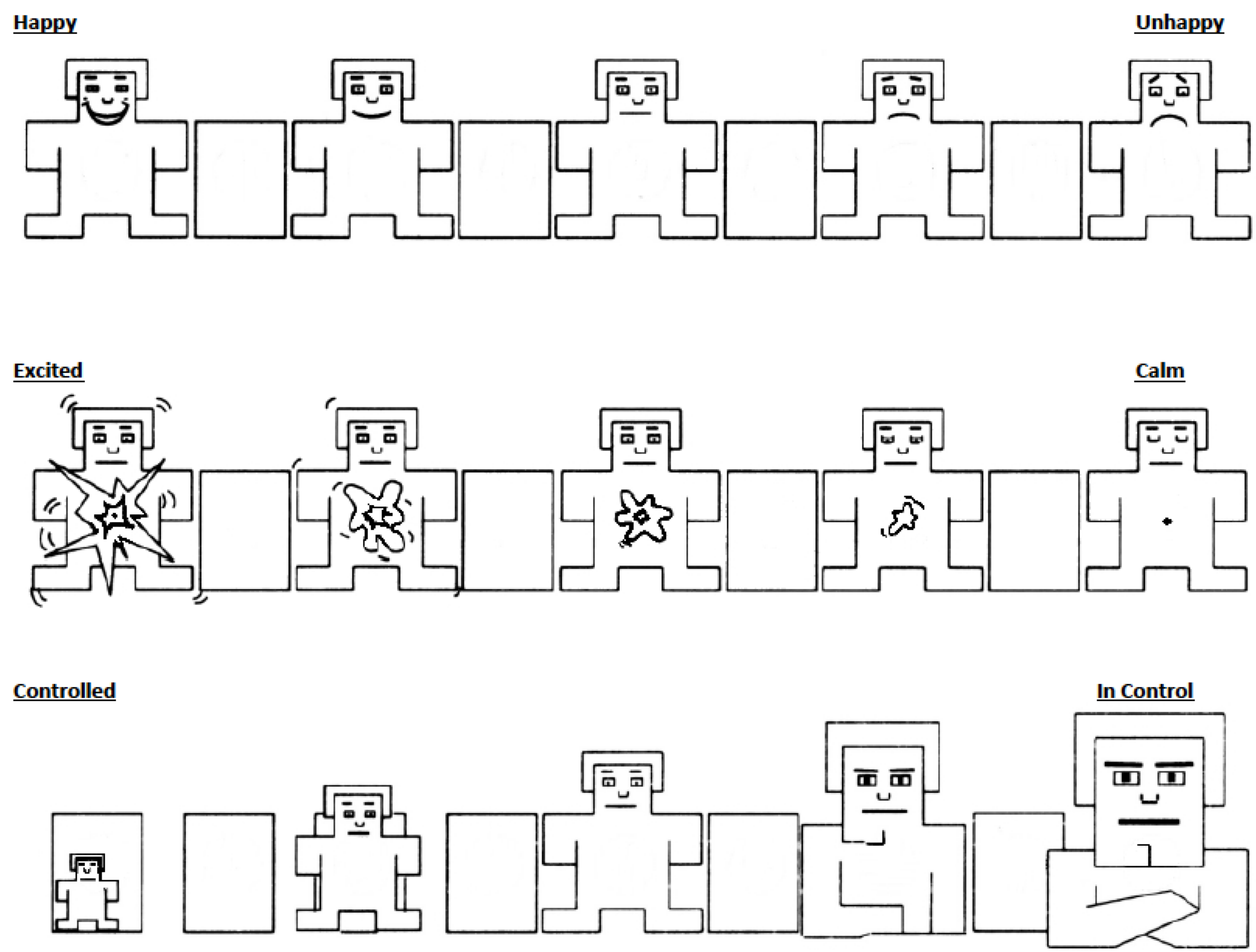

Figure 7. Self-Assessment Manikin measures of valence, arousal and sense of control.

Cognitive Appraisal

I adapted the measures used by Azgarzadeh, Luska, Kogab and Hirate (2012) for this study. Participants were asked to answer the following questions in relation to the building they were placed in front of, on a scale of 1-7 (not at all - very): (1) How oppressed did you feel? (2) How disturbing was this feeling of oppressiveness? (3) How open did you perceive the setting to be? (4) How satisfied were you with the openness? and (5) How friendly was the setting?

Physiological Measure

Electrodermal activity, also known as the galvanic skin response or skin conductance, is the measure of the rate of sweat gland response. It is generally considered to be a reliable index of sympathetic autonomic nervous system activity and indexes roughly with the concept of arousal. In this study, electrodermal activity was measured using a wearable device called the Empatica E4 (Empatica Inc., Milan, Italy) which measures electrodermal activity, heart rate, interbeat intervals, body temperature, and movement from the wrist. This device allows for a wireless measure of this data using Bluetooth and a smartphone application. The main variable of interest for this study was electrodermal activity. The skin conductance level values were averaged and divided into 1-minute intervals to produce five electrodermal activity values per participant. As this was a within subject repeated measures study, skin conductance level values were not z-scored (Stemmler,1987).

Procedure

Study 2a

Participants were taken to two successive locations in Central London (Figure 8), one where they were exposed to a tall building, and the other where they were exposed to a short building. The locations were chosen through a systematic survey of Central London using

Google Earth. Google Earth renders a 3D representation of the Earth, allowing us to scan the city for an ideal location. Clusters of tall buildings were examined, with particular attention paid to easy access to short buildings. It was important to find two locations close together so that the journey between the buildings would not affect the ratings on the SAM, oppressiveness measures, or electrodermal activity. Time, and the process of walking long distances, or using an automobile to transport the participants could potentially affect results. Furthermore, I wanted to choose locations with minimal vehicular traffic, as the noise and visual commotion could also provide confounding effects. The tall building chosen (Figure 10a) was the Leadenhall Building (48 floors), located at 122 Leadenhall Street. The rear entrance backs onto a plaza on a cul-de-sac, on Undershaft Road. The cul-de-sac helped address the issue of vehicular traffic and noise, as it was a dead-end road. Across the cul-de-sac from the Leadenhall Building is the rear of St. Helen's Bishopsgate Church. It is a simple, red brick building (3 storeys). This was chosen to be the short building (Figure 10b). The distance between the two locations was approximately 140 feet, which allowed for a quick transition between the two buildings. 8 participants were randomly assigned to view the tall building first, and 8 participants were randomly assigned to view the short building first. Partial deception was involved; participants were informed that the purpose of the experiment was to compare responses from real-world exposure to virtual reality exposure, which was true, however, they were not informed that the other intention of the study was to measure affective, physiological and cognitive responses to tall buildings. The participants were fitted with the Empatica E4 device on their non-dominant hand. They were then brought in front of the building and were instructed to observe the building for five minutes. After five minutes, they were provided with a paper-pencil SAM and Oppressiveness questionnaire. When those two questionnaires were completed, they were taken to the other building and the same procedure was implemented. A graphical representation of the experimental procedure can be viewed in Figure 9.

Figure 8. Aerial map of study location. (a) low-rise building observation point. (b) high-rise building observation point.

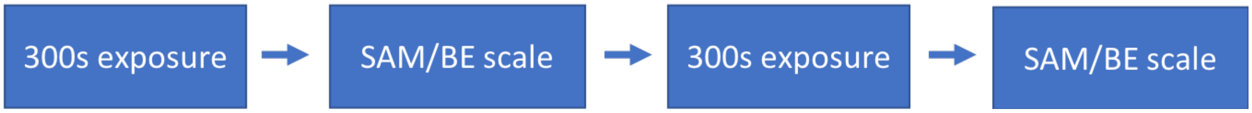

Figure 9. Experimental procedure for both Study 2a and Study 2b

Figure 10. (a) Leadenhall Building (high-rise building). (b) St. Helen's Bishopgate Church (low-rise building)

Study 2b

This was also a within-subjects design where, using immersive virtual reality, participants were exposed to 360-degree video of the short and tall buildings from Study 1. The 360-degree video was captured using a Ricoh Theta V camera; the camera was placed at the exact locations where participants were asked to stand in study 1. The same partial deception used for study 2a was used for study 2b. Participants were fitted with the Empatica E4 bracelet. They were then fitted with the HTC Vive and exposed to a five minute 360-degree video clip of one of the buildings and were instructed to observe the building. Following the five-minute exposure, the HTC Vive headset was removed and participants were asked to complete a paper-pencil SAM and Oppressiveness questionnaire. Following completion, they were then exposed to the other building, and the same procedure was used. Participants were randomly assigned to the order of the conditions, and counterbalancing was ensured. A graphical representation of the experimental procedure can be viewed in Figure 9.

Results

Study 2a

Four sets of analyses were performed. Electrodermal activity values from the 5-minute exposure were averaged and divided into 1-minute intervals to produce five electrodermal activity values per participant; a one-way repeated measures ANOVA was performed on the 1-minute intervals. I found no effect of building height on electrodermal activity. A one-way repeated measures MANOVA was run on openness and openness satisfaction. There was a statistically significant effect of building height on openness (Figure 11), $F(1, 15) = 7.74$, $p = .014$; Wilk's $\Lambda = 0.63$, partial $\eta 2 = .34$. There was no effect of building height on openness satisfaction. A one-way repeated measures MANOVA was also run on the SAM measures of valence, arousal and dominance. There was a statistically significant effect of building height on valence (Figure 12), $F(1, 15) = 9.00$, $p = .009$; Wilk's $\Lambda = 0.54$, partial $\eta 2 = .38$. Lastly, a one-way repeated measures MANOVA was run on the qualitative measures of oppressiveness, disturbingness, friendliness. There were no effects of building height on these measures.

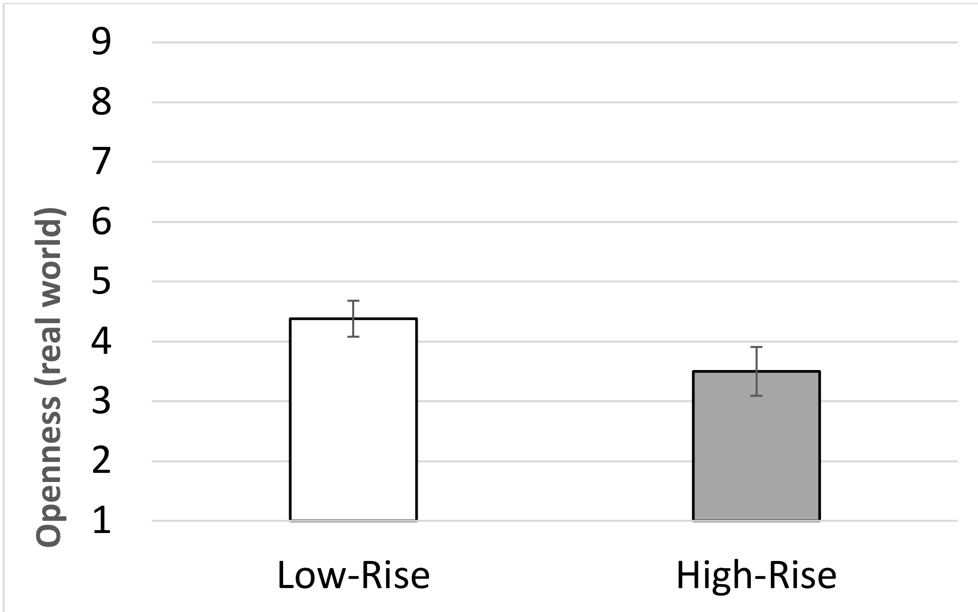

Figure 11. Bar graph showing the influence of building height on openness ratings in real world. Error bars represent ± 1

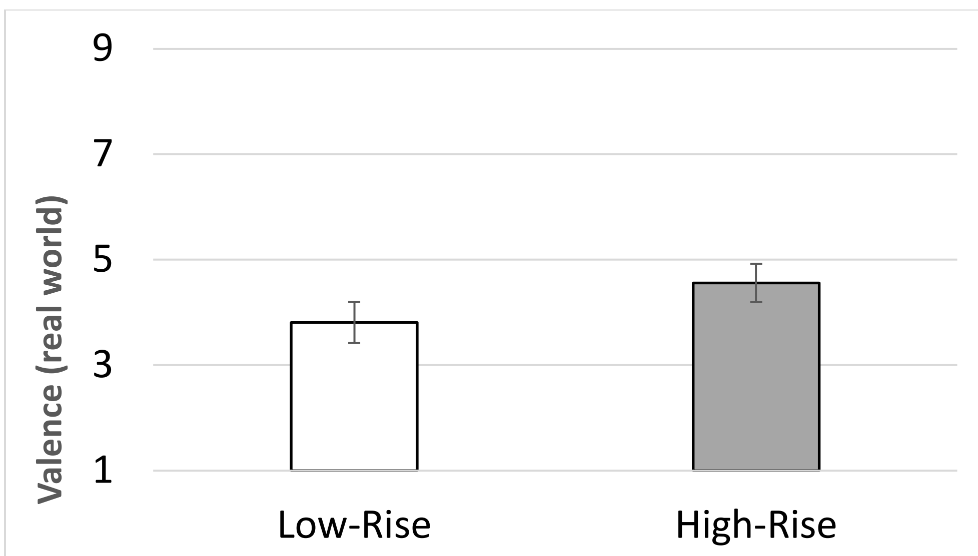

Figure 12. Bar graph showing the influence of building height on negative affect ratings in real world - higher values indicated greater negative affect. Error bars represent ± 1 SEM

Study 2

The same analyses that were run in study 1 were run in study 2. Electrodermal activity values from the 5-minute exposure were averaged and divided into 1-minute intervals to produce five electrodermal activity values per participant; a one-way repeated measures ANOVA was performed on the 1-minute intervals. I found no effect of building height on electrodermal activity. A one-way repeated measures MANOVA was run on openness and openness satisfaction. There was a statistically significant effect of building height on openness (Figure 13), $F(1, 119) = 32.88$, $p < .001$; Wilk's $\Lambda = 0.76$, partial $\eta 2 = .22$, and openness satisfaction (Figure 14), $F(1, 119) = 34.37$, $p < .001$; Wilk's $\Lambda = 0.76$, partial $\eta 2 = .22$. A one-way repeated measures MANOVA was also run on the SAM measures of valence, arousal and dominance. There was a statistically significant effect of building height on valence (Figure 15), $F(1, 119) = 14.12$, $p < .001$; Wilk's $\Lambda = 0.88$, partial $\eta 2 = .11$, and dominance (Figure 16), $F(1, 119) = 6.35$, $p < .001$; Wilk's $\Lambda = 0.88$, partial $\eta 2 = .05$. Lastly, a one-way repeated measures MANOVA was run on the qualitative measures oppressiveness, disturbingness, friendliness. There was a statistically significant effect of building height on friendliness (Figure 17), $F(1, 119) = 34.90$, $p < .001$; Wilk's $\Lambda = 0.75$, partial $\eta 2 = .23$.

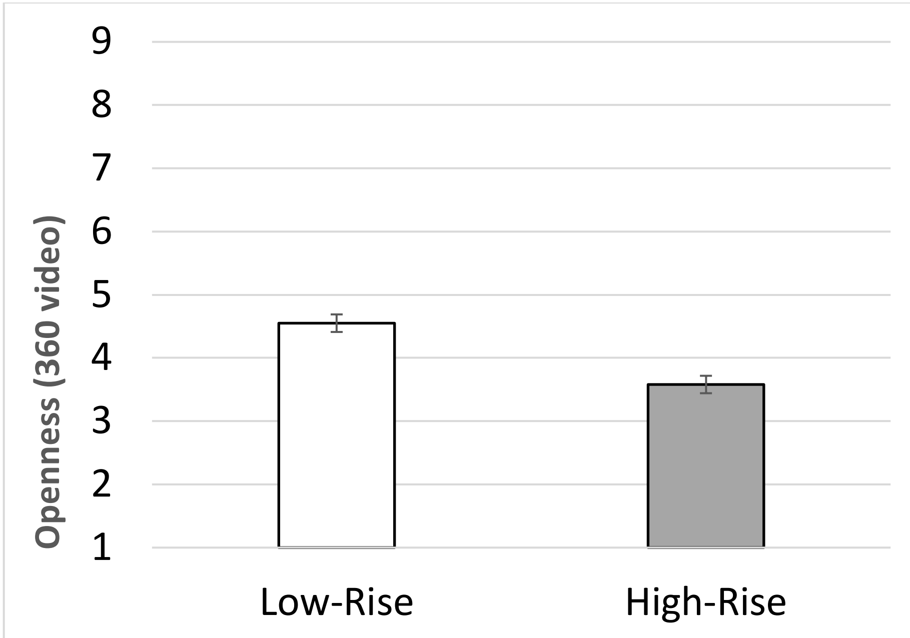

Figure 13. Bar graph showing the influence of building height on openness ratings in virtual reality. Error bars represent ± 1 SEM.

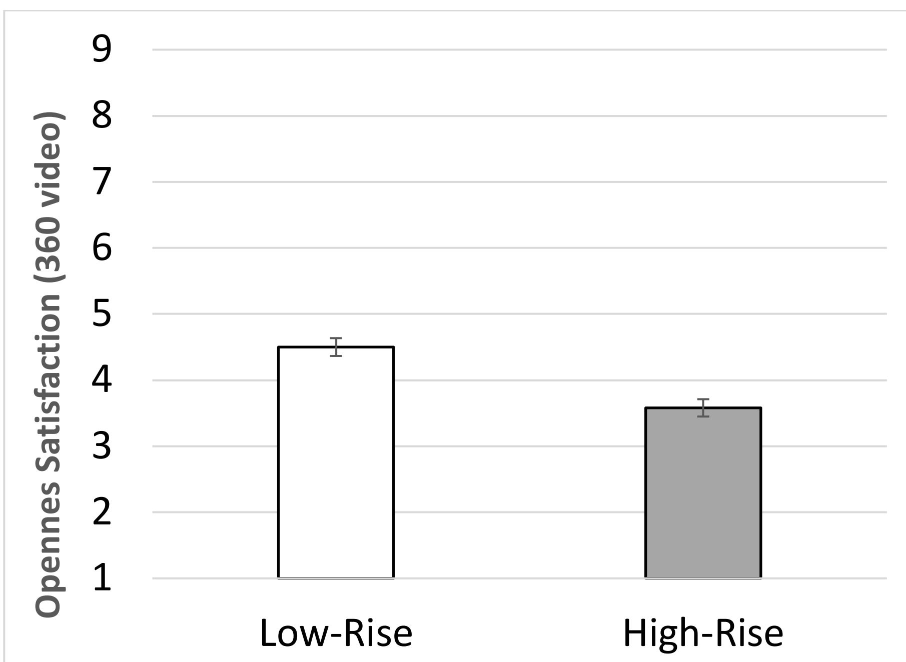

Figure 14. Bar graph showing the influence of building height on openness satisfaction ratings in virtual reality. Error bars represent ± 1 SEM

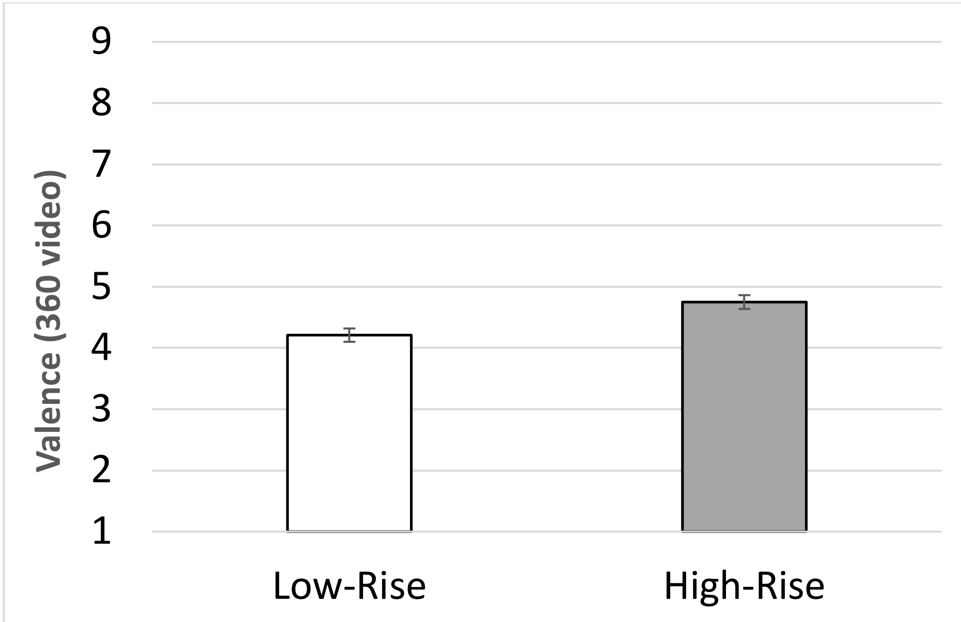

Figure 15. Bar graph showing the influence of building height on negative affect ratings in virtual reality - higher values indicated greater negative affect. Error bars represent ± 1 SEM.

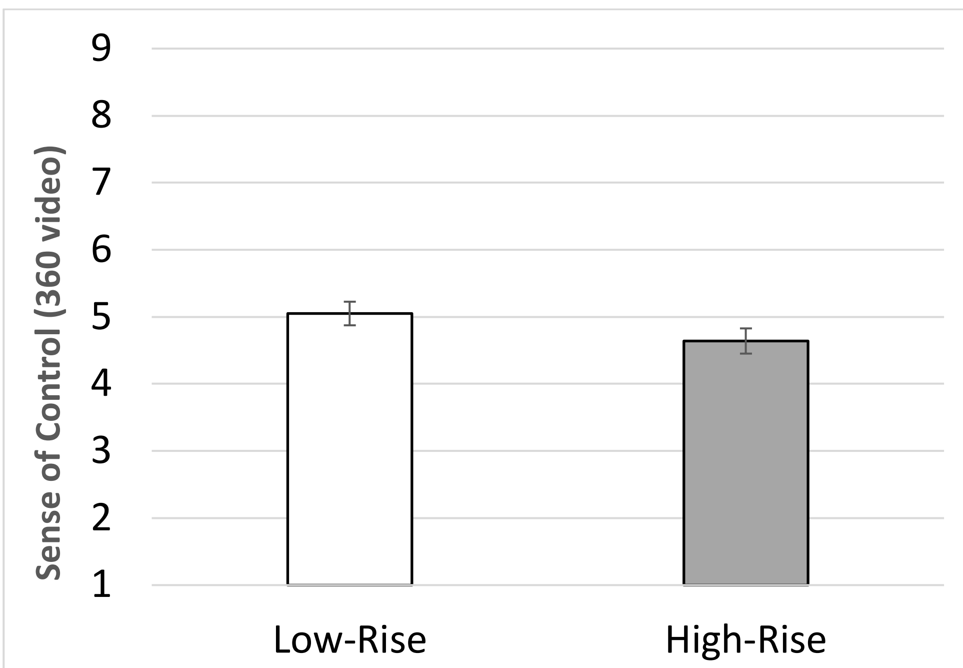

Figure 16. Bar graph showing the influence of building height on dominance ratings in virtual reality. Error bars represent ± 1 SEM

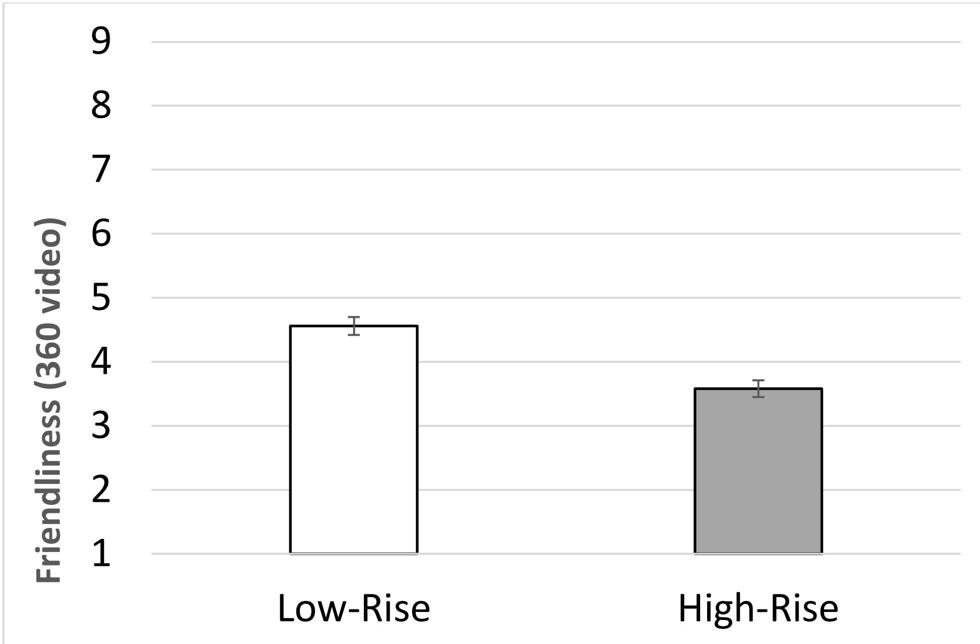

Figure 17. Bar graph showing the influence of building height on friendliness ratings in virtual reality. Error bars represent ± 1 SEM

Comparing Study 2a and Study 2b

In addition to understanding how building height influenced electrodermal activity, openness, openness satisfaction, valence, arousal, dominance, oppressiveness, disturbingness and friendliness, this study was also designed to assess whether 360-degree video displayed in immersive virtual reality could be used as an approximation of the real world. To do this, I ran one-way ANOVAS comparing each of the variables previously mentioned between real world and virtual reality conditions. There were no statistically significant differences for any of the measures. Figure 18 and 19 show the influence of short versus tall buildings on negative valence, and openness. They were representative of the pattern shown for all of the variables assessed and highlight the similarity in the results gleaned from the real world and virtual reality study.

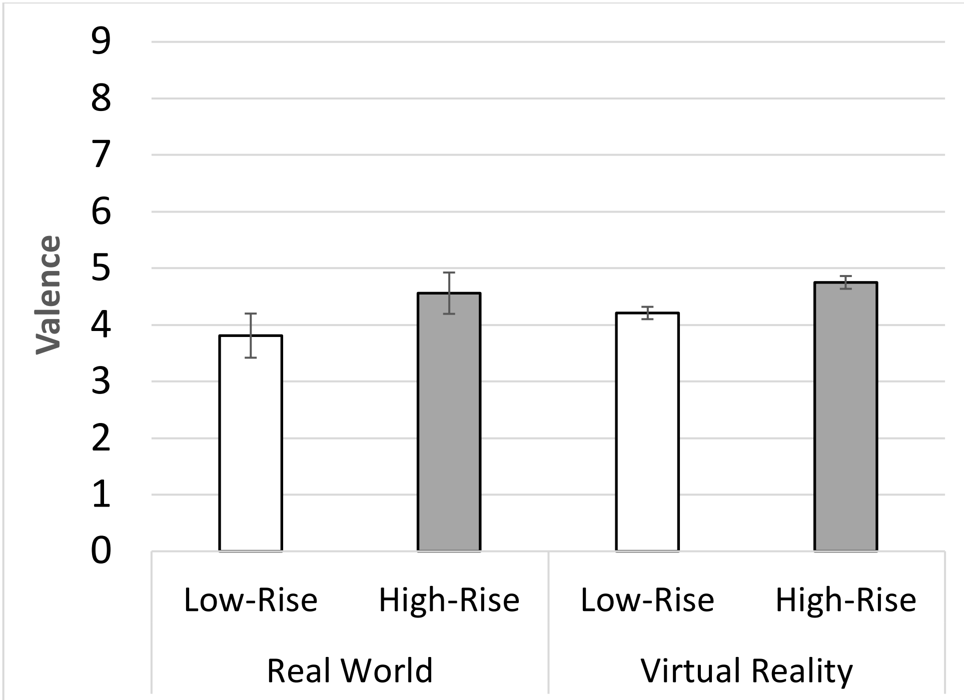

Figure 18. Bar graph showing the influence of building height on negative valence ratings in real world and virtual reality. Error bars represent ± 1 SEM.

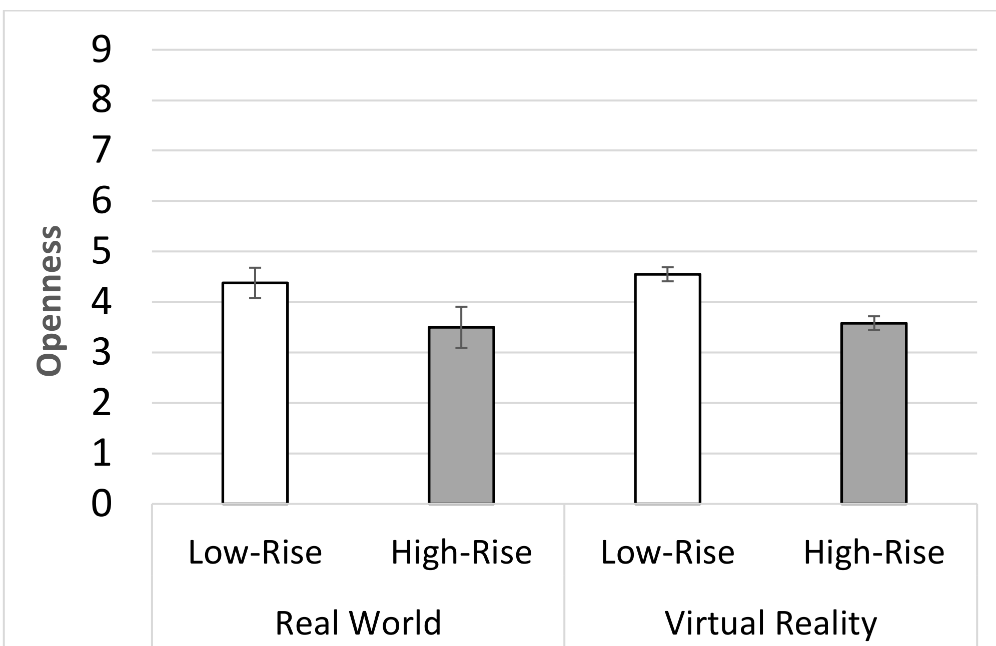

Figure 19. Bar graph showing the influence of building height on openness ratings in real world and virtual reality. Error bars represent ± 1 SEM.

Discussion

Our study demonstrated that people found high-rise buildings, as compared to low-rise buildings, in a real-world setting, to be associated with higher ratings of negative affect, less openness and less friendliness. I found similar effects in virtual reality, through use of an HMD and 360-degree video. The 360-degree video study allowed for a larger sample size and helped confirm our hypothesis that tall buildings would be associated with lower openness satisfaction and lower sense of control.

The low-rise building setting was rated as being more open and that (in our sample with video) participants were more satisfied with the openness, which aligns with previous research. In their work on environmental preferences, Kaplan, Kaplan & Brown (1989) identify four domains of predictors for scene preference: land form (i.e slope of land), land cover (i.e forestation), informational variable (i.e complexity) , and perception-based variables (i.e openness). Of the four domains, perception-based variables, namely openness, had the strongest predictive power for scene preference. Kaplan & Kaplan (1989) state, “the spatial configuration that for nature consistently generates favorable responses involves areas that are open, yet defined.” People prefer an open view, as it allows them to assess their environment more easily and understand the affordances within it (Kaplan & Kaplan, 1989). Assessing the interior spaces and openness, Bokharaei and Nasar (2016) found that perceived spaciousness was positively associated with preference. Also examining interior spaces, Vartanian et al. (2015) found people avoid enclosed spaces and found them to be less beautiful. In the urban context, perceived openness was found to correlate with neighbourhood satisfaction (Hur, Nasar & Chun, 2010). In his book, *Exterior Design of Architecture*, Ashihara (1970) explores the relationship between building height and the space between buildings, suggesting that when the height of buildings exceeds the space between them that “we feel a sense of being closed in that builds up to a kind of claustrophobia.” (p 43). Ewing and Handy (2009) state that “buildings become the ‘walls’ of the outdoor room” (p 74). In their study on the effects of oppressiveness of high-rise buildings, Asgarzadeh, Luska, Kogab and Hirate (2012) using pictures, demonstrated that high-rise buildings were associated with lower openness ratings. They describe oppressiveness as a being related to an invasion of personal space. Accordingly, this invasion of space could in fact be connected to how enclosure causes a sense of impediment of movement. Stamps and Smith (2002) state “it is possible that a space could give the impression of enclosure without limiting what can be seen.” These findings also aligned with the work of Stamps (2005), who, through exposing research participants to pictures of urban built environments, found building height was positively correlated with ratings of enclosure.

In the Probabilistic Model of Aesthetic Response, Nasar (1994) suggests that aesthetic responses to buildings, specifically, involve both a cognitive and an affective component, identifying scale as a formal aesthetic attribute. While the existing literature measured enclosure (Lindal & Hartig, 2013; Stamps, 2010; Stamps & Smith, 2002), here I also measured the impact of being in the presence of high-rise buildings on an individual’s emotional state. To our knowledge, these studies are the first that uses an established psychological assessment to measure affective responses to high-rise buildings. Through use of the SAM, I was able to measure how building height influenced affect; I found a significant effect of building height on affect in both the real world and the virtual setting. The increase in negative affect induced by tall buildings could potentially lead to a longer-term impact on physiology through stress responses. A study by Beil and Hanes (2013) comparing very natural and very built environments, found environments with the most buildings to be associated with the highest concentration of salivary amylase, a hormone associated with stress. This suggests urban settings that are densely populated by high-rise buildings could have negative effects on an individual's emotional state. Results from our 360-degree video study also demonstrate that participants rated themselves as having a lower sense of self control when exposed to the tall building. This aligns with work done by Joye & DeWitte (2012), who suggest that tall buildings evoke negative awe. They found that participants felt smaller when exposed to taller buildings, as compared to being exposed to smaller buildings. Evans & McCoy (1998) suggest that largeness of buildings is associated with institutionalization, which can cause feelings of powerlessness. Cochrane (2012) who views high-rise buildings as large objects that invoke feelings of sublimity, suggests that these structures provoke people to think the structures are "'very' powerful, or 'much more powerful than me" (p.144). Baum and Baum (1981) suggest that perceived control over an environmental stressor has a powerful effect on how that stressor is experienced; there is nothing one can do about being in the presence of high-rise buildings, other than not expose themselves to these environments which is increasingly challenging in urban environments. A sense of control may also be tied to the visual permeability of the environment (Stamps, 2005); tall buildings can obstruct an individual's ability to survey the surrounding area. Furthermore, it has been suggested that Medieval Churches were designed to be tall and imposing, to elicit feelings of smallness and insignificance. (Maass et al, p 75, 2000). In this light, our findings on the SAM measure of dominance make sense. Participants also found the low building setting friendlier, suggesting that this environment was more approachable and pleasant. All of our findings, taken into concert, suggest that the high-rise building setting was less desirable than the low building setting.

Our study also has methodological implications, confirming that 360-degree video viewed within an HMD can be used as a viable alternative to real world exposure, which aligns with an assertion made by Rohrman and Bishop (2002) who state, "for an environmental simulation to be considered valid it should evoke a similar set of responses as would a direct experience of the same environment" (p. 320). A study by Yuhan, Lange & Thwaites (2015) found that 360-degree panoramic photos were more effective in allowing participants to appraise a landscape than typical 60-degree photos. Furthermore, Higuera-Trujillo, Moldonado and Millan (2017) examined the validity of the use of photos, panoramic photos and virtual environments to simulate real environments. They found that panoramic photos were the most realistic, as measured by psychological responses, and virtual reality environments were the most realistic, as measured by physiological responses. Our study utilized 360-degree videos, which combines elements of both panoramic photos and virtual reality; 360-degree videos are essentially panoramic videos viewed within a virtual environment, and so they address both the psychological and physiological components of emulating the experience of the built environment. This approach aligns with the environmental psychology school of transactionalism, which recognizes the complexity of studying the dynamic experience of an individual in an environment.

There are many challenges associated with studying the psychological experience of urban environments. Doing field research in the city can require extensive organizational efforts and planning. These extra efforts can reduce the number of participants that can be run. More importantly, even at a given location, each participant experiences slight differences where the sound, weather, and number of people present can vary. The confounds within this methodology must be acknowledged and addressed in this field of research; the 360-degree video method offers a potential solution. It addresses the complexity of scheduling and meeting participants in the field and allows testing to be done in the lab; it also ensures participants are exposed to the exact same visual inputs within a location thereby increases confidence that any effects are due to the factors of interest as opposed to other peripheral variables. , Brehmer and Dormer (1993) suggest that the challenge of most psychological research is the inability to handle complexity. They state: “In field research, there is often too much of it to allow for any more definite conclusions, and in laboratory research, there is usually too little complexity to allow for any interesting conclusions” (Brehmer & Dormer, 1993, p.172). This particular research is measuring the impact of the field *on* the participant. And so, field research can’t be replaced entirely. However, 360-degree video in concert with virtual reality offers an interesting compromise between traditional picture-based laboratory experiments and field research. By maximizing the naturalistic elements within a laboratory context, external validity and experiential realism can be increased (Kort et al, 2003) but at the same time, some empirical control can be effected to ensure that the effects seen are due to the variables of interest as opposed to other spurious factors.

One weakness of this study is that neither the real world or the 360-degree video study yielded significant effects of building height on oppressiveness. Previous studies which found effects of building height on ratings oppressiveness recruited architectural students as participants; there is a possibility that architectural students are more familiar with the concept of oppressiveness, which may be more of an abstract construct for psychology students to grasp; some study participants were unsure about the meaning of the word (Azgarzadeh, Luska, Kogab and Hirate, 2012; Azgarzadeh et al. 2014; Zarghami et al. 2019). I did, however, get significant effects of building height on openness. These findings may indicate that openness is a more concrete and understandable construct to measure. It is also possible that our findings, from the pictorially presented SAMS, that indicate building height has a negative impact on sense of control can also speak to the oppressive quality of high-rise buildings. I also did not obtain any significant results of electrodermal activity. I suspect this is due to the fact that the Empatica E4 records electrodermal activity from the wrist, as opposed to the palm, where there are much higher densities of eccrine sweat glands. While the density of eccrine sweat glands vary per person, it is understood that the highest density of eccrine sweat glands in the human body are at the palms, soles of the feet, arm pits, and forehead (Saga, 2002). In a study examining the reliability of electrodermal activity recording sites, Payne, Schell and Dawson (2016) found that the wrist had the lowest responsiveness, while the fingers, considered to be the gold standard for electrodermal activity recording, had the highest responsiveness; 31% of responses evoked at palmar sites were not evoked at the wrist. Furthermore, electrodermal activity readings taken at wrist sites were found to be moderately correlated with electrodermal activity readings taken at the palm (van Dooren, de Vries & Janssen, 2012). Another issue with recording at the wrist is the confound of added thermoregulatory sweat gland activity. Payne, Schell and Dawson (2016) state, "locations such as the wrist, where sweat glands respond to temperature as well as to psychological states, may be confounded in terms of causality of SCRs, given that in ambulatory SC recording, sweat gland activation due to temperature changes and physical exertion is likely." (p. 1088).

Our research joins a growing body of work that demonstrates that urban environments shape our psychological state (Ellard, 2015; Goldhagen, 2017; Montgomery, 2013). The methodology used to examine the psychological impacts of urban design in the lab setting has evolved over the years, from having participants appraise photos (Kaplan & Kaplan, 1979), to having research participants imagine themselves in different settings (Thiel, Harrison & Alden, 1986), to taking people out into the real world (Azgarzadeh et al, 2014; Negami et al, 2019), to displaying 2D images on a large, angled screen (Azgarzadeh, Luska, Kogab and Hirate, 2012; Zarghami et al. 2019), to our current study where I both took people out in the real world and placed them in immersive 360-video environments using a virtual reality headset and used psychological measures to assess their experience. Nasar (1994) recommends that attention should be paid to the visual character of a building for the sake of the public good. Our findings suggest that building height can have a negative impact on an individual's emotional state. Mayor of London, Sadiq Khan, has directed individual boroughs in London, which is seeing an upswell of high-rise buildings across the city, to decide how tall high-rise buildings should be and to consider if the spatial context and character is suitable to them (City of London, 2020). It is a compromise between character and housing utility in a city that is faced with a massive shortage in housing (reference). The following is an excerpt from the City of London's *Draft New London Plan* (2020) on tall buildings that suggests the following is considered:

> "Immediate views [of high-rise buildings] from the surrounding streets [need to be considered] – attention should be paid to the base of the building. It should have a direct relationship with the street, maintaining the pedestrian scale, character and vitality of the street. Where the edges of the site are adjacent to buildings of significantly lower height or parks and other open spaces, there should be an appropriate transition in scale between the tall building and its surrounding context to protect amenity or privacy."

The plan further states that, "buildings near the River Thames, particularly in the Thames Policy Area, should not contribute to a canyon effect along the river which encloses the open aspect of the river." This policy clearly acknowledges the visual impact of high-rise buildings on the street level and nearby open green and blue spaces. The New London Authority (2020), a non-profit organization that focuses on the effects of the built environment, suggests that high-rise buildings should be "good neighbours visually" (p. 50). It is encouraging to see this focus on the atmospheric stressors that can be caused by exposure to high-rise buildings. The findings from these studies, can provide empirical psychological support to policies that stand to inform the visual experience of London, and other cities facing similar issues. That the City of London, a "world" city, is directly addressing the elements examined in this dissertation, should signal that these research questions are of practical use, and have implications far beyond the laboratory. As cities continue to densify, it is important that a psychological lens is applied to the process of urbanization.

Chapter 4: Examining the Effect of Distance from High-Rise Buildings on Affect

Combined, Studies 1, 2a and 2b all demonstrated that exposure to high-rise buildings can have negative impacts on affect. All 3 studies involved having participants being exposed to the buildings from a static position, meaning that distance was not varied. Study 3 aimed to examine how distance from a high-rise building moderated affective and cognitive measures. This question is important to ask, as the previous research on the subject implicated the perception of invasion of space by high-rise buildings as a potential reason for inducing negative affect. Arguably, distance from high-rise buildings would influence affect ratings. Ashihara (1970) suggests that people can feel "claustrophobic" when surrounded by high-rise buildings. A study by Stamps (2005) found that building height was associated with ratings of enclosure. Perceived enclosure has been implicated in limiting what can be seen, and from the perspective of evolutionary psychology, has been suggested to be tied to prospect and refuge, or, an individual's ability to survey their area while staying safe. Asgarzadeh, Lusk, Koga, and Hirate (2012) conducted a study where they examined "oppressiveness", which is reported to be a sensation felt when around high-rise buildings. Oppressiveness has been related to proxemics, and it has been suggested that high-rise buildings elicit a feeling similar to that of the invasion of personal space. When an individual's space is invaded, they experience stress and negative affect (Evans & Wener, 2007; Kanaga & Flynn, 1981; Long, Selby, & Calhoun, 1980). Previous research on the psychological effects of high-rise buildings has shown that, in addition to height of the building, proximity is also of importance. It has been suggested that the closer an individual is to a building, the higher the ratings of oppressiveness (Takei & Oohara, 1978; Hwang, 2007; Zarghami et al, 2019). The majority of research examining the psychological impacts of being in the presence of high-rise buildings involve showing participants pictures. It is our belief that in order to adequately induce and measure a feeling of invasion of space, a more ecologically valid approach must be used. For Study 3, I chose to examine the effects of distance from the Toronto Dominion (TD) Building using 360-degree pictures presented in an HMD, which provides a more realistic experience of high-rise buildings than two-dimensional pictures.

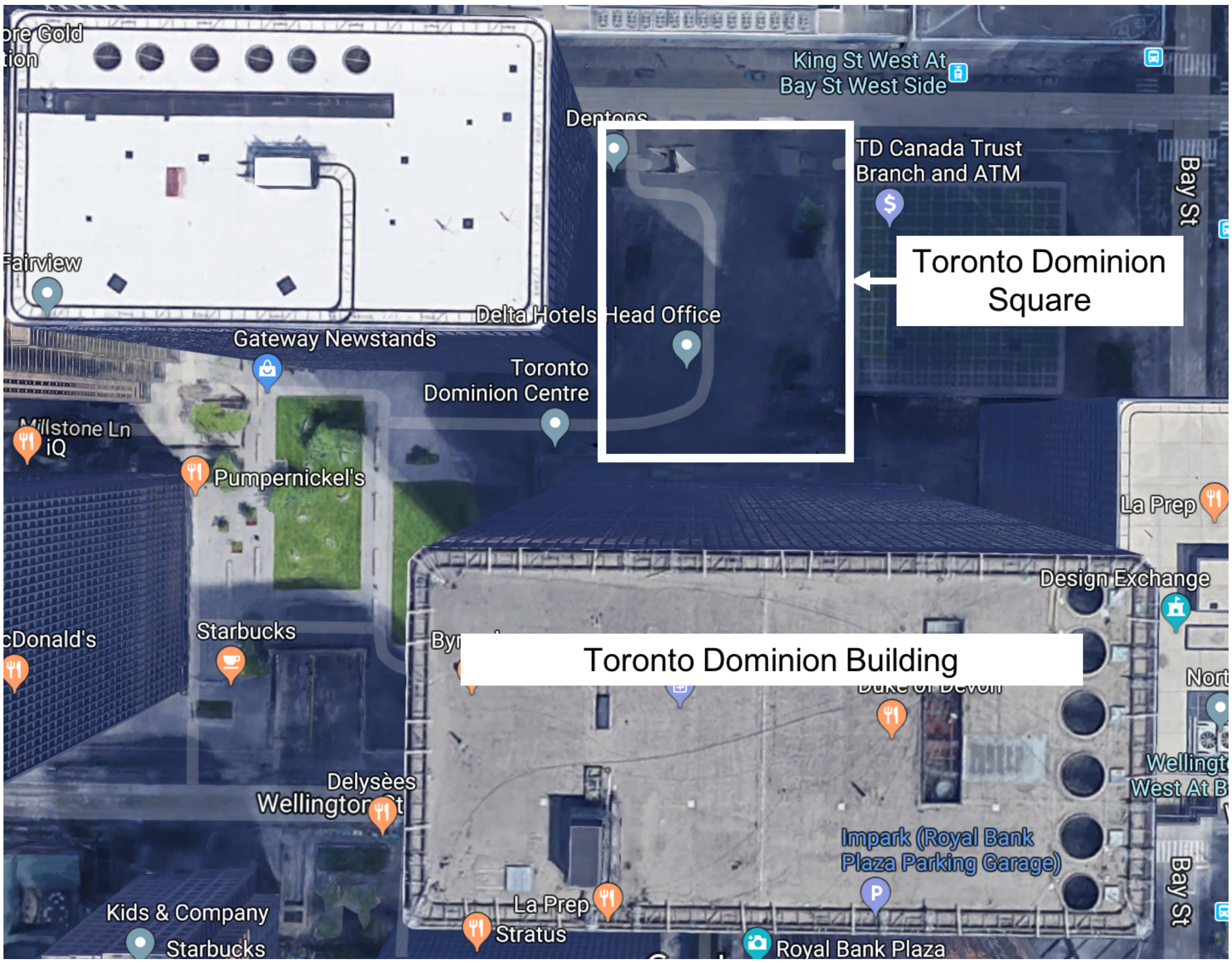

Figure 20. Aerial map of study location.

The TD Building (Figure 20) is 56 stories tall and located in downtown Toronto, Canada. It was chosen for its height, but also because it is adjacent to Toronto Dominion Square, a large sparse square with an absence of benches or locations to congregate. This was of benefit for two main reasons: (1) Due to the poor design of the square, it is generally not occupied, which would allow pictures of the building to be taken with minimal people in the setting. This is important, as the presence of people could be a potential confound. The second, and perhaps more important, reason the site was optimal for this experiment was that the square allowed pictures to be taken of the building from various distances. High-rise buildings typically line urban streets, so taking a clear picture, from the distances used in this study, would not be possible on a street. The street would also be populated with cars and people, which would further complicate obtaining the pictures and would introduce confounds in a study where I was exclusively interested in how distance from a high-rise building moderate affect and cognitive appraisal. The square allowed us to take to take pictures from three distances: 7.38 m (close), 15.98 (mid-range), and 23.41 m (far). The setting allowed us to adequately manipulate distance and examine the effects, which were measured using an openness scale, which measures scene openness, and the Self-Assessment Manikin (SAM), which measures affect, arousal and sense of control. Departing from the cognitive appraisal scales used in studies 1, 2a and 2b which included oppressiveness, disturbingness, friendliness, openness and openness satisfaction, I chose to focus only on openness in this study. In an attempt to keep the survey simple and quick, I wanted to focus on one cognitive appraisal variable and felt that openness provided interesting spatial information. I hypothesized that the closer an individual is to the high-rise building, the higher the negative affect, the higher the arousal, the lower the sense of control, and lower the openness would be. I chose not to use electrodermal activity as a measure for this study, due to the fact that the multiple exposures to conditions (6 exposures in total) would disrupt the ability to obtain a suitable, continuous measure of electrodermal activity. Furthermore, the disruption and movement associated with donning and removing the HMD numerous times would affect the participant's level of arousal and accordingly the integrity of the electrodermal activity recordings.

Materials and Methods

A total of 100 undergraduate students (76 female, Average Age = 20.24 years) were recruited from the University of Waterloo undergraduate research pool between May 2019 and August 2019. Students participated in order to receive course credit in psychology courses. This study received ethical approval from the University of Waterloo's Office of Research Ethics (ORE #21656, approved 22 August 2016).

Apparatus

HTC Vive

360 photos were presented to participants using a HTC Vive headset. The device features a resolution of 2160X1200 pixels with a field of view of 110 degrees. The device weighs approximately 555 grams and features three adjustable straps to ensure a tight and comfortable fit.

Environments

To reiterate, I was interested in how distance from a high-rise building influenced an individual's affect, arousal, sense of control and ratings of openness. I wanted to assess these effects within an immersive virtual environment; 360-degree photos of the Toronto Dominion (TD) Building, located in Toronto, Ontario, were taken from three distances: 7.38 m (close), 15.98 m (mid-range) and 23.41 m (far). The TD building is 222.8 m tall and is one of the tallest buildings in Toronto. To ensure the effects measured were driven by the distance from the Toronto Dominion building alone, I edited out surrounding buildings, using the Gnu Image Manipulation Program (GIMP), an open source photo editing software. While using photos provided the ability to take pictures while the square was free of people, there were still people in the lobby of the building. Therefore, using I also used GIMP to blur the lobby area of the building. Blurring the lobby of the building ensured that the presence of people in the setting did not influence ratings of affect, arousal, sense of control and openness. Participants were exposed to 6 environments in total: close (Figure 21a), close blurred (Figure 12b), mid (Figure 21c), mid blurred (Figure 21d), far (Figure 21e), far blurred (Figure 21f).

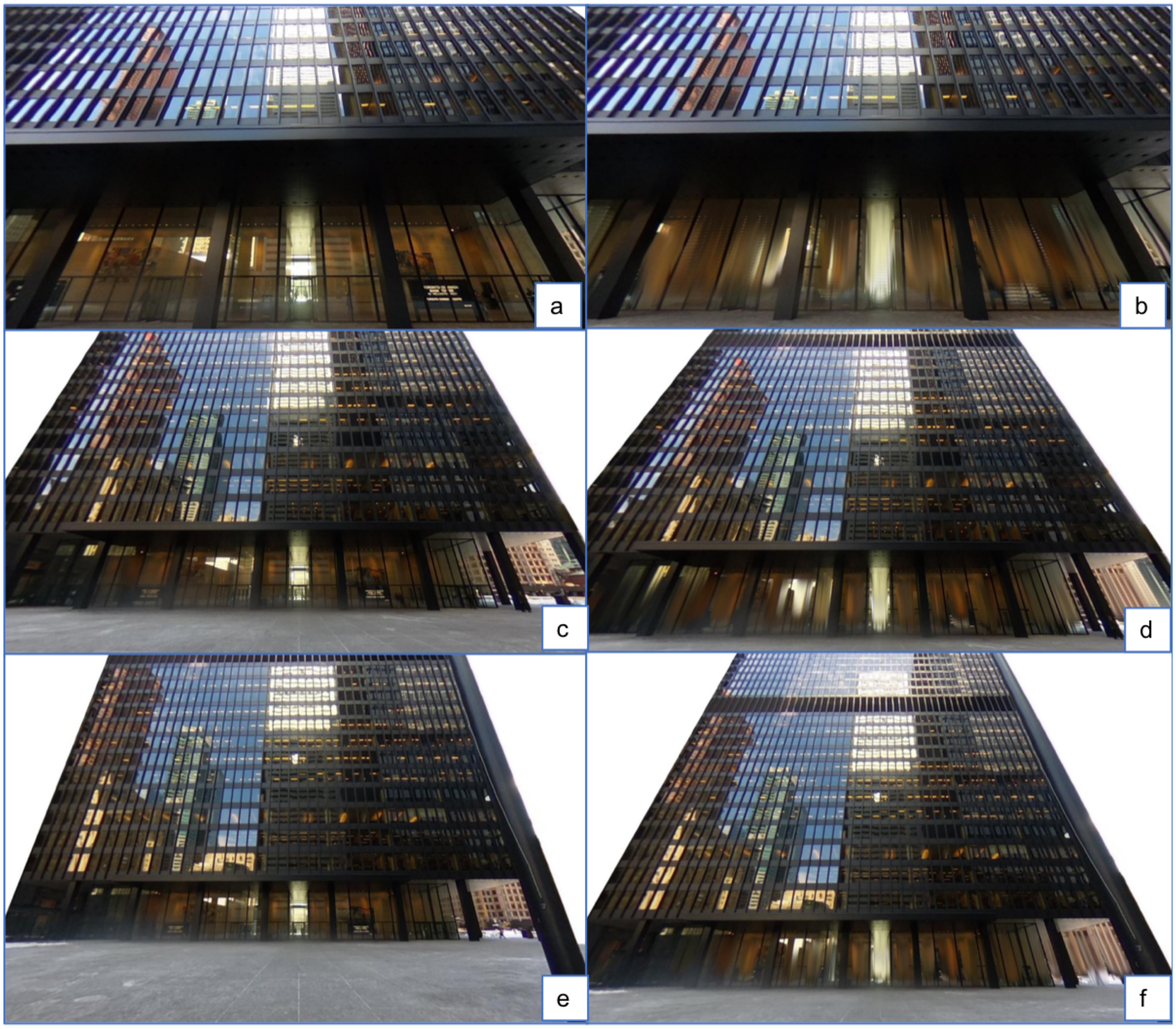

Figure 21. (a) Close unblurred (b) Close blurred (c) Mid unblurred (d) Mid blurred (e) Far unblurred (f) Far blurred

Measures

Affect Measure

The self-assessment manikin (SAM) (Figure 22) is a pictorial measure that assesses valence, arousal and dominance (sense of control). The SAM was developed in response to the semantic differential model (Mehrabian & Russel, 1974), as it was determined the semantic differential model, at 18 9-point-scale questions, was too cumbersome to use to measure these constructs. The SAM was intended to measure responses to objects and events, and therefore was appropriate to measure the affective response to the TD Building.

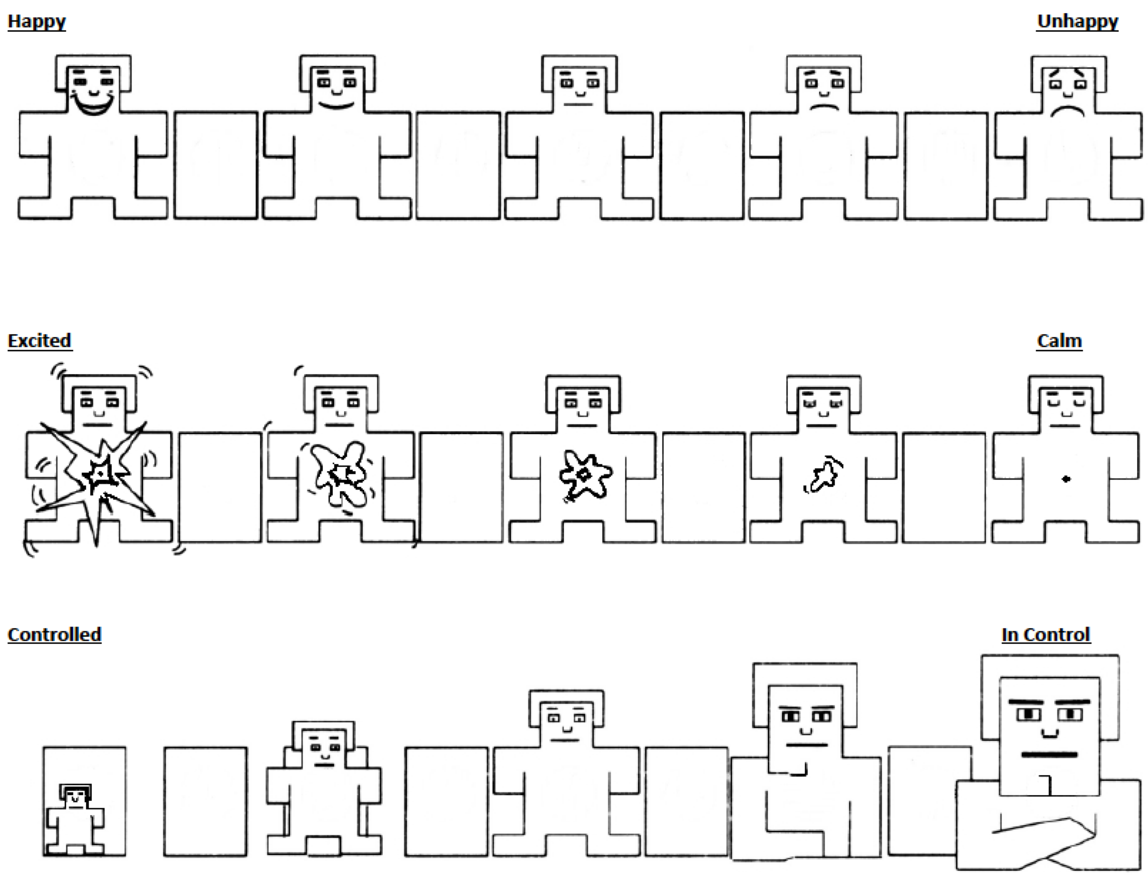

Figure 22. Self-Assessment Manikin measures of valence, arousal and sense of control.

Cognitive Appraisal

Participants were asked to answer the following question in relation to the building they were placed in front of on a scale of 1-7 (not at all-very): How open did you perceive the setting to be?

Procedure

This was a within-subjects study. Using the HTC Vive virtual reality headset and VR Photo Viewer, a 360-degree photo viewing application, participants were exposed to the 6 different environments in random order. Deception was used in this study. To ensure that participants didn't focus on the lobby area of the building, they were informed that the intention of this study was to examine how the presence of people influenced their perceptions of a building, and that their ability to view the lobby would be manipulated. Each environment was presented for 30 seconds and participants were directed to continually scan the building in its entirety. After each 30 second exposure, participants were asked to complete the SAM and the openness questionnaire on a computer. A graphical representation of the experimental procedure can be viewed in Figure 23.

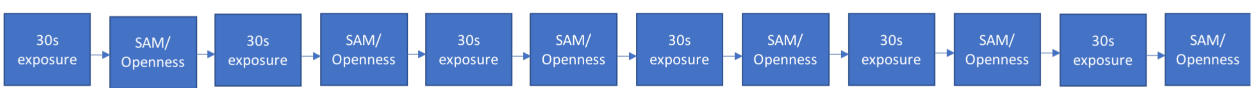

Figure 23. Experimental procedure for Study 3.

Results

Study 1

A one-way repeated measures ANOVA was conducted to examine the effects of distance from the TD building on openness. For all analyses, only the blurred conditions were used. As mentioned earlier, the manipulation of blurring was done to ensure the lobby of the building and presence of people in it did not act as confounds that could potentially affect ratings. The presence of people in urban scenes has been found to ameliorate feelings of threat (Jorgensen et al., 2013), which is being examined in this study. Distance was found to have a significant effect on openness (Figure 24), $F(1, 103) = 12.17$, $p < .001$; partial η2 = .11. Participants rated the farthest viewpoint as being the most open, and the closest as being the least open. A pairwise comparison showed a significant difference between the close and the mid ($p = .001$) and the close and the far ($p < .001$). Participants were least happy the closest to the building, and most happy the furthest from the building.

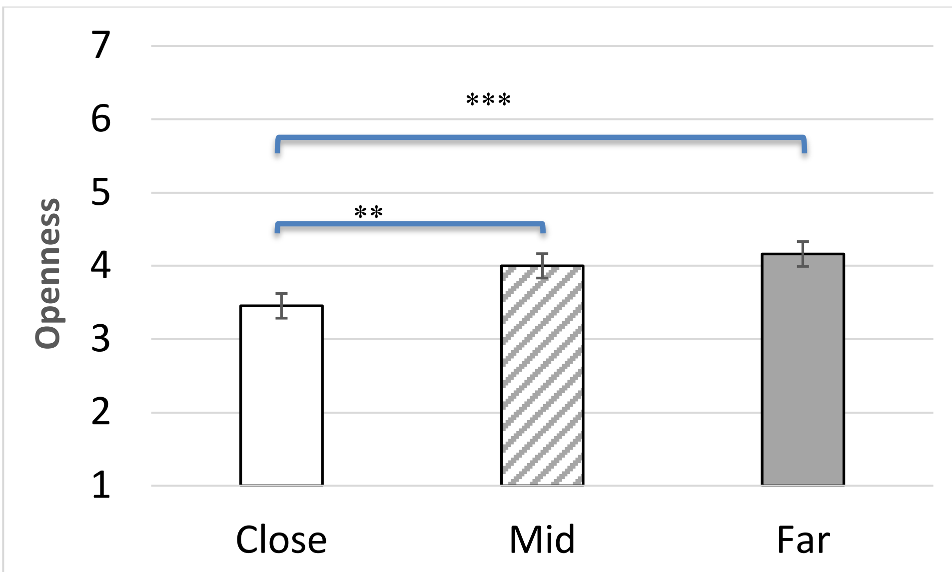

Figure 24. Bar graph showing the influence of distance from building in on openness. Error bars represent ± 1 SEM. Significant differences are denoted with asterisks. *** p < .001, **p < 0.05.

A one-way repeated measures MANOVA was run to examine the effects of distance on the SAM measures of valence, arousal and dominance. There was a statistically significant effect of distance on valence (Figure 25), $F(1, 103) = 10.19$, $p < .001$; Wilk's Λ = 0.83, partial η2 = .09. Participants were least happy the closest to the building, and most happy the furthest from the building. A pairwise comparison showed significant differences between the close and mid (p= .01) and the close and far ($p < .001$), but not between mid and far.

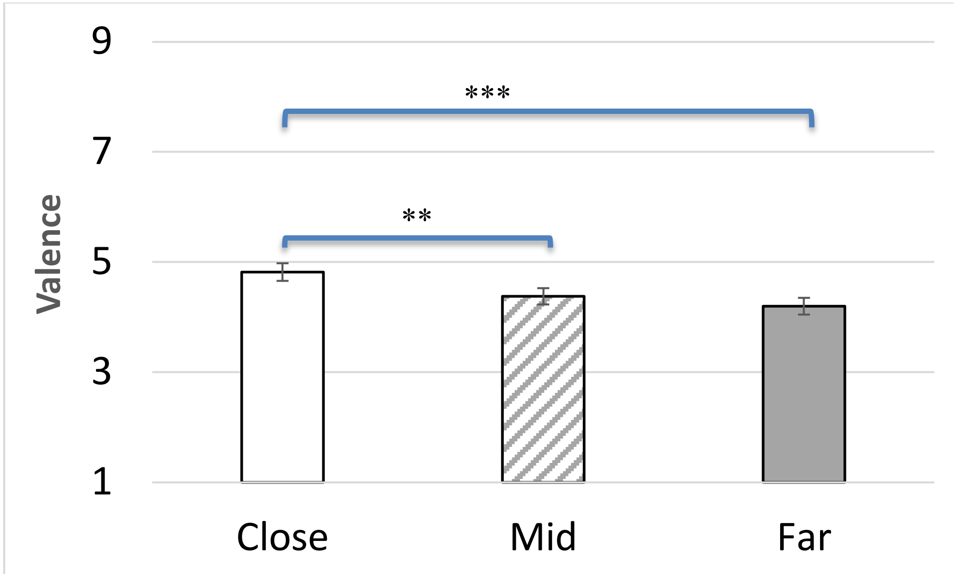

Figure 25. Bar graph showing the influence of distance from building in on valence - higher values indicated greater negative affect. Error bars represent ± 1 SEM. Significant differences are denoted with asterisks. *** $p < .001$, **$p < 0.05$

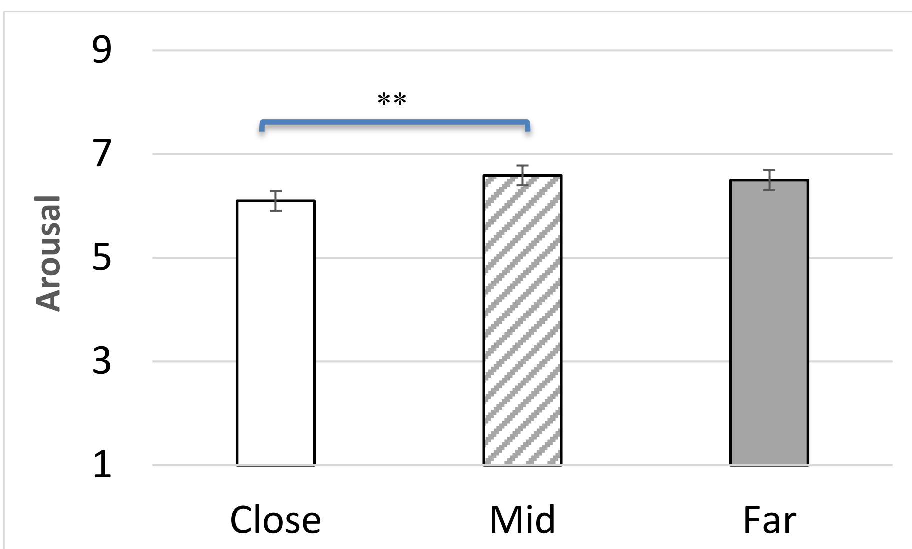

Figure 26. Bar graph showing the influence of distance from building in on arousal. Error bars represent ± 1 SEM. Significant differences are denoted with asterisks. **$p < 0.05$.

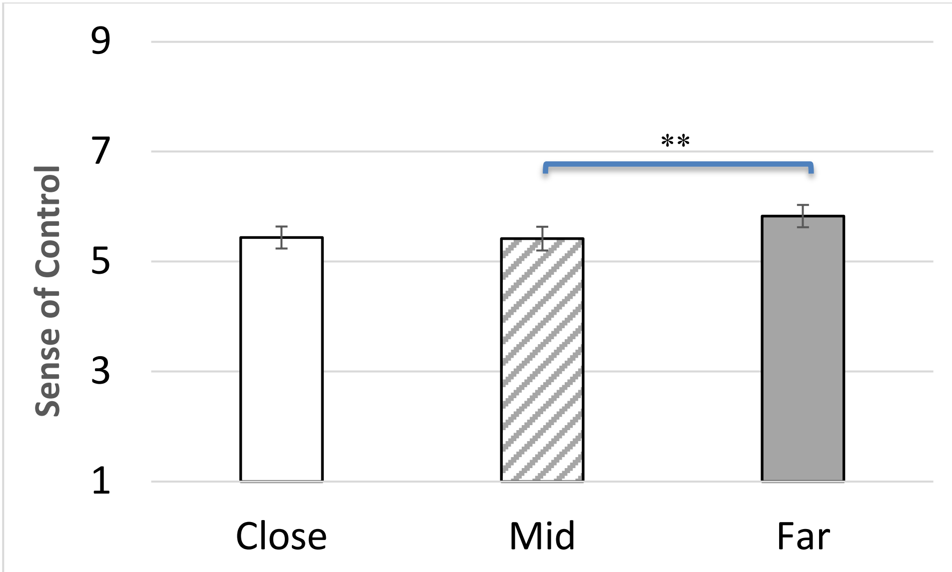

Figure 27. Bar graph showing the influence of distance from building in on sense of control. Error bars represent ± 1 SEM. Significant differences are denoted with asterisks. **p < 0.05.

There was a significant effect of distance on arousal (Figure 26), $F(1, 103) = 5.13$, $p = .007$; partial $\eta 2 = .05$. Participants experienced the highest level of arousal at the mid-point, and the lowest level of arousal furthest from the building. A pairwise comparison showed significant differences between close and mid ($p = 0.01$), but not between close and far, or mid and far. There was also a significant effect of distance on sense of control (Figure 27), $F(1, 103) = 3.67$, $p = .027$; partial $\eta 2 = .04$. Participants felt most in control furthest from the building, and least in control at the mid-point. A pairwise comparison showed only a significant difference between the mid and the far ($p = 0.02$).

Discussion

Results from Study 3 confirmed all of our hypotheses and suggest that the closer an individual is to a high-rise building, the less happy, more aroused, and less in control they feel. Participants also rated their environments as more open, the farther they were from the building.

Spreiregen (1963) suggested a ratio of 1:1 of distance between buildings to building height for full enclosure; Ashahira (1970) claimed that a ratio of less than 1 caused a feeling of claustrophobia. It is then expected that most cities with dense concentrations of high-rise buildings can induce a sense of claustrophobia, which is defined as “a situational phobia featuring intense anxiety in relation to enclosed spaces and physically restrictive situations.” (Lourenco, Longo, & Pathman, 2011). Claustrophobia, which is the fear of enclosed spaces, has been examined through the lens of proxemics. Edward Hall (1966) coined the term proxemics, which he defined as the “interrelated observations and theories of man's use of space” (p 101). Proxemics has also been defined as “the study of our perception and structuring of interpersonal and environmental space.” (Harrigan, 2005, p 137). Hall (1966) stated that proxemics involves an individual’s spatial relationship to other people, moveable objects (interior decor) and fixed-space objects, like buildings. Hall (1966) elaborates by stating, “scale is a key factor in planning towns, neighborhoods, and housing developments (p 170). To our knowledge, our study was the first to examine the proxemic relationship between people and buildings using immersive virtual reality and standardized psychological measures - specifically assessing the impact of distance from buildings on emotion and appraisals of openness. This is perhaps due to the fact that an invasion of space causes a negative emotional response. It is possible that the perception of an invasion of space caused by the built environment can elicit a similar response to that of the invasion of space by another person. Peripersonal space is also a function of emotional state; an individual’s perception of their space being invaded can be influenced by their response to external variables perceived to be a threat (Ferri, 2015). Zadra and Clore (2011) suggest that an individual’s emotional state can influence their perception of the environment that surrounds them. There may be a feedback loop between the negative affect caused by the built environment and the peripersonal boundaries an individual establishes, meaning that an individual's affect is influenced by their environment, which then influences their perception of their environment (Ferri, 2015). Winkel, Saegert and Evans (2009) suggest that the environment can affect cognitive appraisals, which in turn can mediate responses. Similarly, arousal has been shown to increase when an individual's space is perceived to be invaded (Middlemist, Knowles & Matter, 1976; Llobera et al, 2010). This aligns with our findings from the SAM, which demonstrate that arousal ratings increased the closer an individual was to the TD building. A study done by Stamps (2011) demonstrated that distance has an effect on the perception of threat; the closer an individual is to a perceived threat, the more threatening they perceive it to be. In the study, the threat was another person, where, in addition to distance, visual cues of eye condition, gender, facial expression, and posture were manipulated. Distance had the strongest effect, while posture was second most impactful on threat. While human posture cannot be directly translated to architectural form, it bears considering that the design of the building itself, specifically its imposing qualities related to its size and design, could play a role in the effects noticed. Amos Rapoport (1990) suggests that meaning is embedded within the built environment and that the design of our surroundings is a form of communication. He cites size and scale of buildings as design variables that can be used to confer dominance over those who exist in or around them . Maass et al (2000) found that building design considered to be intimidating had an effect on the comfort of research participants. Discussing the design of churches built after the Romantic period, they suggest that elements of the architecture, including height, caused people to feel "small, vulnerable, insignificant" (Maass et al, p 75, 2000). In this light, our findings on the SAM measure of dominance make sense. I found that the farther away an individual was from a building, the higher the ratings of sense of control. Evans & McCoy (1998) suggest that largeness of buildings is associated with institutionalization, which can cause feelings of powerlessness. Lastly, aligned with previous work (Asgarzadeh et al., 2012, 2014), this study demonstrates that the amount of visual space a building occupies can influence the psychological impacts. Distance from a building modulates the visual pressure it has. In previous research done on building height, it was not possible to parse out the aesthetic variables of materiality or design from the effects of building height on psychological variables of interest; through using the same building and manipulating distance from it we were able to clearly establish that the perceived mass of the building was responsible for the effects we found.

The intention of this study was to explore how the distance from a high-rise building influences our psychological state. The findings of this study suggest that distance from high-rise buildings, and the distance from them, have a negative effect on an individual's emotional state, as measured by both psychological and subjective physiological measures of arousal. While these findings are preliminary, they suggest that attention be paid to building height in urban centres. Wider sidewalks, setbacks, and attention to the use of podiums all have implications on the distance an individual is from the building. These findings also support the need for more open spaces in cities, such as public squares and parks; the surrounding built environment should also be considered. The *Tall Building Guidelines* developed by the City of Toronto (2013) suggest a horizontal separation distance (Fig x) between high-rise buildings and between high-rise buildings and low-rise buildings and open spaces in an effort to preserve sky view, or in other words, openness.

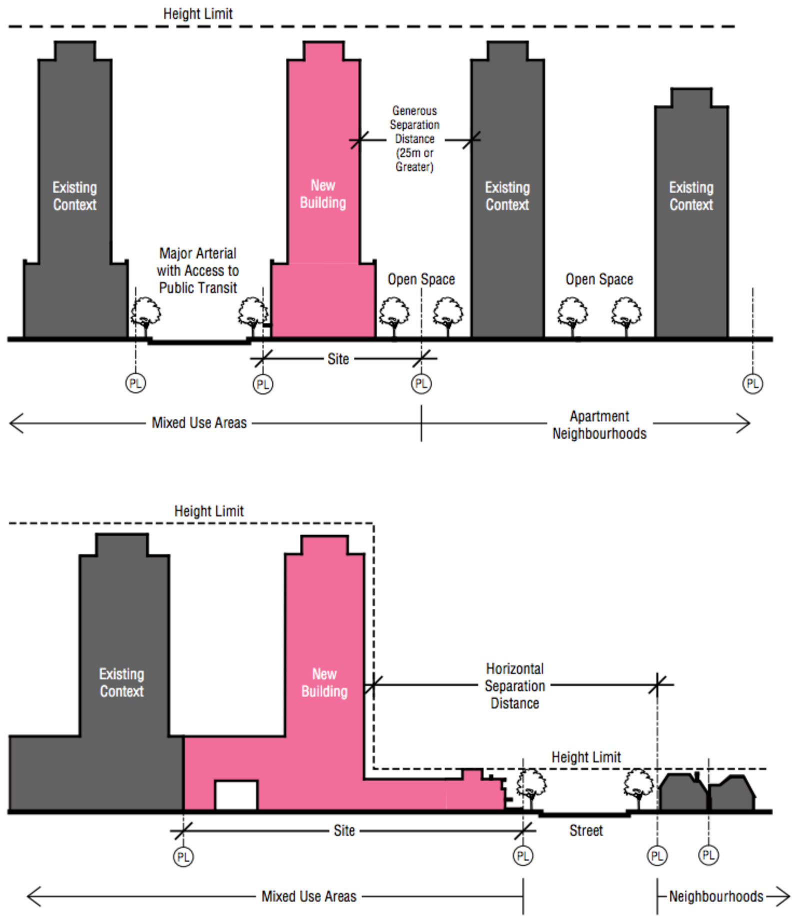

Figure 28. High-rise building design guidelines emphasizing the importance of horizontal distance (City of Toronto, 2013).

Parakh, Gabel, and Safarik (2017) state, "spaces between and alongside tall buildings cannot feel overwhelmed by these structures, but rather, should be complimented by them" (p. 204). They don't explicitly state what they mean by "overwhelm", but I would suggest that the findings of this study provides insight into what may overwhelm someone when they are in the presence of high-rise buildings; participants experienced higher arousal, higher negative affect and less sense of control, the closer they were to a high-rise building. I would argue that these findings suggest the experience of being overwhelmed. It is uplifting to see practitioners acknowledge the psychological implications of high-rise buildings, and the proximity to them.

As cities continue to densify and build upward, these considerations are necessary to ensure the wellbeing of urban residents.

Chapter 5: Psychological and Physiological Effects of Exposure to Multiple Buildings

For study 5, I wanted to explore how exposure to multiple buildings influenced electrodermal activity, affect, as measured by the Self-Assessment Manikins, and cognitive appraisal, specifically openness. I chose to conduct this study for two reasons. First, I wanted to ensure the effects shown in previous studies would generalize across different building exemplars that differed in height – in other words despite having potential differences in the aesthetics of the buildings shown, building height would still incite changes in feelings of arousal, negative affect and the feeling of being overwhelmed. Winkel, Saegert and Evans (2009) suggest that a problem in environmental psychology is "sampling considerations are typically focused on the representativeness of the participants rather than the representativeness of the setting." In real-world research, this is understandable, given the logistics of transporting participants to a number of settings. However, virtual reality allows us to transport participants to different settings instantly, giving us more freedom to examine the effects of multiple contexts. Accordingly, I used combinations of 20 different buildings to ensure an adequate sampling of environments. Second, in an attempt to address ecological validity, I wanted to acknowledge that the experience of the city does not entail remaining in a static position and looking at only one building. I wanted to take advantage of the realism of 360-degree video, while exposing participants to a number of buildings. As opposed to manufactured virtual environments, 360-degree video is limited in its capabilities in that participants cannot freely explore the virtual environments they are placed in; the video is taken from a static position and only allows the user to modify their yaw and pitch and limiting their parallax from different viewpoints. I had considered using a 360-degree camera on a stabilizing grip to capture a moving video of a cityscape, however I was concerned about the accompanying motion sickness, considering the research participant would be in a seated position. Therefore, I opted to "teleport" research participants between each of the settings, through stitching videos together.

In this study, I revisited the question of whether exposure to high-rise buildings would not only induce measurable psychological responses, but also physiological responses as measured by electrodermal activity. Electrodermal activity is considered to be the best indicator of sympathetic nervous activity, which controls the fight or flight response, as eccrine sweat gland activity is directly controlled by the sympathetic nervous system, whereas other physiological indicators like heart rate and blood pressure are also controlled by the parasympathetic nervous system (Dawson et al, 2011). Electrodermal activity is considered to be an indicator of emotional response (Boucsein, 2012) and electrodermal activity is considered to be the best physiological indicator of anxiety (Dawson et al, 2011). I wanted to examine the effects of high-rise buildings on Electrodermal activity using the best instrumentation available to us. In study 1, I used the Shimmer, which transmitted information wirelessly through Bluetooth and had a sampling frequency of 15.9 hz, however due to connectivity issues I lost a considerable number of files. Considering the number of lost files, I did not want to use the Shimmer again. In studies 2a and 3b, I used the Empatica E4, as it was considered one of the best wearable electrodermal activity devices, with a sampling rate of 4 Hz. However, the Empatica collects measurements at the wrist, which has been shown to be one of the least ideal locations to measure electrodermal activity due to a low density of eccrine sweat glands and the confound of co-occurring thermoregulatory sweating (which is not an issue when measured at the palm or foot) which can cloud the actual effects of the setting on emotional sweating (Payne, Schell & Dawson , 2016). Therefore, I opted to use the ADI Powerlab GSR +, which is a wired device, in contrast to both the Shimmer and the Empatica E4. The ADI Powerlab GSR+ also samples at 1000 HZ, which is significantly greater than the previous devices used. Brathwaite et al (2000) suggest that a higher sampling rate is ideal to increase precision. I was interested in optimizing for electrodermal activity measurement because I wanted to see if our findings in study 1, which demonstrated an effect of high-rise manufactured buildings on electrodermal activity, could extend to 360-degree video environment, which I believe is a more ecologically valid setting. Bower, Tucker and Enticott (2019) state that measures like electrodermal activity, "require precise and measured experimental conditions to ensure the reaction is to the stimulus being tested rather than to a confounding variable in the setup (such as temperature, ambient noise, associated memory)" (p. 9). Unlike Studies 2a and 2b, I wasn't seeking to compare responses to the locations used in this VR study to real world responses, therefore I did not use audio to limit the confound of urban noise in the settings, and to recognize the fact that noise would be different for all 20 locations used and would affect comparability. It is also important to note that the ADI Powerlab GSR + is not portable for use in a real world setting; a lab based 360 video HMD set up may be the best compromise in methodology to understand how building height affects electrodermal activity. I deemed it important to show that building height would impact a physiological measure like electrodermal activity, because subjective variables cannot tell a complete story of the influence the environment has on an individual. Edelstein and Macago (2012) suggest that while subjective psychological measures are helpful, they require a subject's understanding and/or awareness of the constructs being assessed, and therefore suggest that neuroscientific methods provide more of an objective measure.

In an effort to examine how prior experience, specifically upbringing, could influence measures, following the experiment (to ensure they weren't primed), I asked participants whether they grew up around skyscrapers. Imamoglu (2000) suggests that previous experience and familiarity with a built environment can render appraisals on a similar environment to be more pleasant. Regular exposure to high-rise buildings could possibly affect habituation, ameliorating responses to these settings. Mandler (1975) proposed that previous experiences, in concert with the cognitive appraisals of the stimuli actively being experienced produces an autonomic nervous system response, which could be considered to be an affective response. Purcell (1986) suggests that an affective response to the built environment is produced when there is a discrepancy between that environment and the "prototype" an individual has in their mind. If someone has very limited experience with urban environments populated by high-rise buildings, it could be contended that exposure to these environments would produce a greater affective response. As mentioned earlier, electrodermal activity is a measure of autonomic nervous system activity. This measure, in conjunction with the SAM and openness scale, provides a means of providing compelling construct validity in the measurement of the affective response to high-rise buildings. For this study, I hypothesized that exposure to high-rise buildings would yield higher electrodermal activity as compared to exposure to low-rise buildings, and that people who grew up around skyscrapers would yield lower electrodermal activity. I also hypothesized that exposure to high-rise buildings would yield higher negative affect, higher arousal, a lower sense of control, and lower openness ratings as compared to exposure to low-rise buildings, and that upbringing would mediate these measures.

Materials and Methods

A total of 104 undergraduate students (85 female, Average Age = 19.54 years,) were recruited from the University of Waterloo undergraduate research pool between September 2019 and December 2019. Students participated in order to receive course credit in psychology courses. This study received ethical approval from the University of Waterloo's Office of Research Ethics (ORE #21656, approved 22 August 2016).

Apparatus

HTC Vive

360-degree videos were presented to participants using an HTC Vive headset. The device features a resolution of 2160X1200 pixels with a field of view of 110 degrees. The device weighs approximately 555 grams and features three adjustable straps to ensure a tight and comfortable fit.

Environments

I was interested in how building height influenced electrodermal activity, affect, arousal, sense of control and ratings of openness. I wanted to assess these effects within an immersive virtual environment; 20 second 360-degree videos were taken of 10 low-rise buildings and 10 high-rise buildings. The low-rise buildings were located in downtown Kitchener, Ontario, a medium sized city. The high-rise buildings were located in downtown Toronto, Ontario, Canada's largest city. A total of 16 stimuli sets were created: 8 compilations of 5 low-rise buildings videos stitched together and 8 compilations of 5 high-rise building videos stitched together (Figures 29-44). The compilations were designed to ensure that a single building did not drive the effect, which allows us to make conclusions about the effect of building height on the measures used.

Figure 29. Low-rise building environment 1.

Figure 30. Low-rise building environment 2.

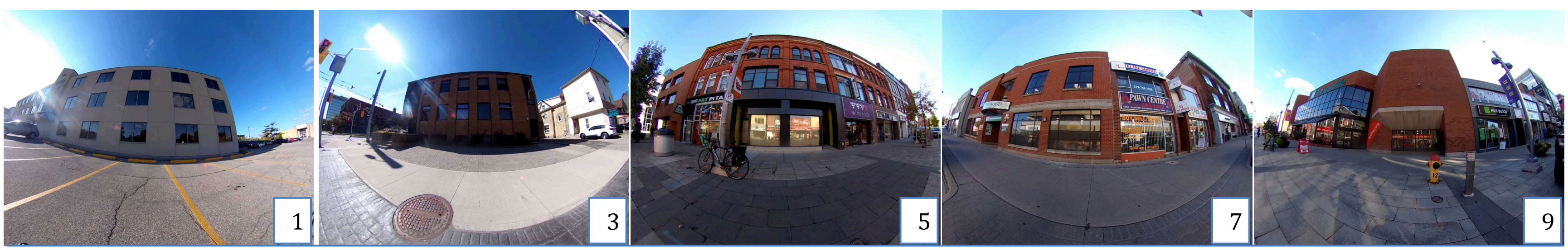

Figure 31. Low-rise building environment 3.

Figure 32. Low-rise building environment 4.

Figure 33. Low-rise building environment 5.

Figure 34. Low-rise building environment 6.

Figure 35. Low-rise building environment 7.

Figure 36. Low-rise building environment 8.

Figure 37. High-rise building environment 1.

Figure 38. High-rise building environment 2.

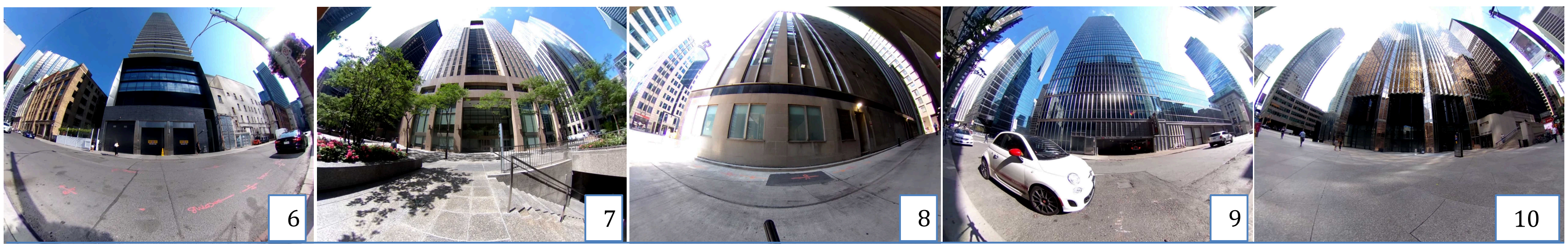

Figure 39. High-rise building environment 3.

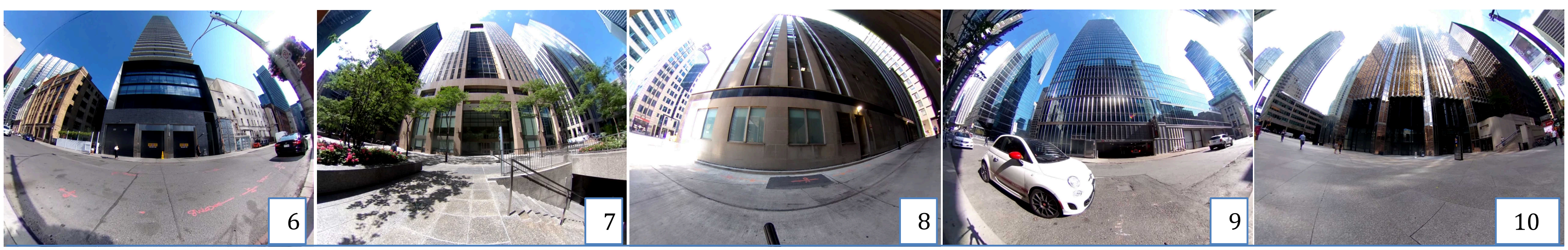

Figure 40. High-rise building environment 4.

Figure 41. High-rise building environment 5.

Figure 42. High-rise building environment 6.

Figure 43. High-rise building environment 7.

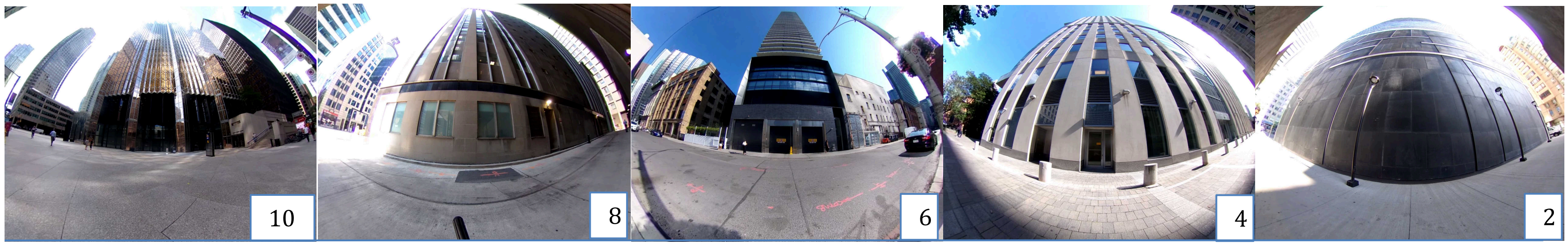

Figure 44. High-rise building environment 8.

Measures

Affect Measure

The self-assessment manikin (SAM) is a pictorial measure that assesses valence, arousal and dominance (sense of control). The SAM was developed in response to the semantic differential model (Mehrabian & Russel, 1974), as it was determined the semantic differential model, at 18 9-point-scale questions, was too cumbersome to use to measure these constructs. The SAM was intended to measure responses to objects and events, and therefore was appropriate to measure the affective response to the TD Building.

Cognitive Appraisal Measure

Participants were asked to answer the following question in relation to the building they were placed in front of, on a scale of 1-7 (not at all - very): How open did you perceive the setting to be?

Physiological Measure

Electrodermal activity, also known as the galvanic skin response or skin conductance, is the measure of the rate of sweat gland response. It is generally considered to be a reliable index of sympathetic autonomic nervous system activity and indexes roughly with the concept of arousal. In this study, electrodermal activity was measured using an ADI PowerLab 4SP which samples at 1000 hz. A 180s baseline reading was taken prior to exposing the participants to the immersive virtual environments to (a) ensure they were at rest prior to exposure. The skin conductance levels for the exposure to both low-rise and high-rise buildings were averaged to produce a skin conductance level value. Skin conductance level is used as opposed to skin conductance responses as it is considered to be more appropriate to use to examine the effect of continuous stimuli (Dawson et al, 2011).

Procedure

This was a within-subjects study. Using the HTC Vive virtual reality headset and DeoVR (Infomediji, Llublana), a 360-degree video application, participants were exposed to one of the 8 low-rise environments and one of the 8 high-rise environments in what for each participant was a random order. Deception was used in this study. Participants were informed that the intention of the study was to compare responses in virtual reality to responses in the real world. Prior to each exposure, a 180s baseline was taken to ensure participants were at rest. During each exposure, electrodermal activity was recorded using the PowerLab GSR Amp. After each exposure, participants were asked to complete the SAM and the openness questionnaire on a computer. After the questionnaires were completed, participants were asked to indicate whether they grew up around skyscrapers.

Results

A mixed-model repeated measures ANOVA with upbringing as a between-subjects factor to examine the effects of building height on electrodermal activity was conducted. There was a main effect of building height on electrodermal activity; exposure to high-rise buildings evoked higher electrodermal activity as compared to exposure to low-rise buildings (Figure 46), $F(1,99) = 9.46$, $p = .003$; partial η2 = .09. The interaction effect of upbringing and building height on electrodermal activity was non-significant, $F(1,99) = 2.92$, $p = .09$; partial η2 = .03.

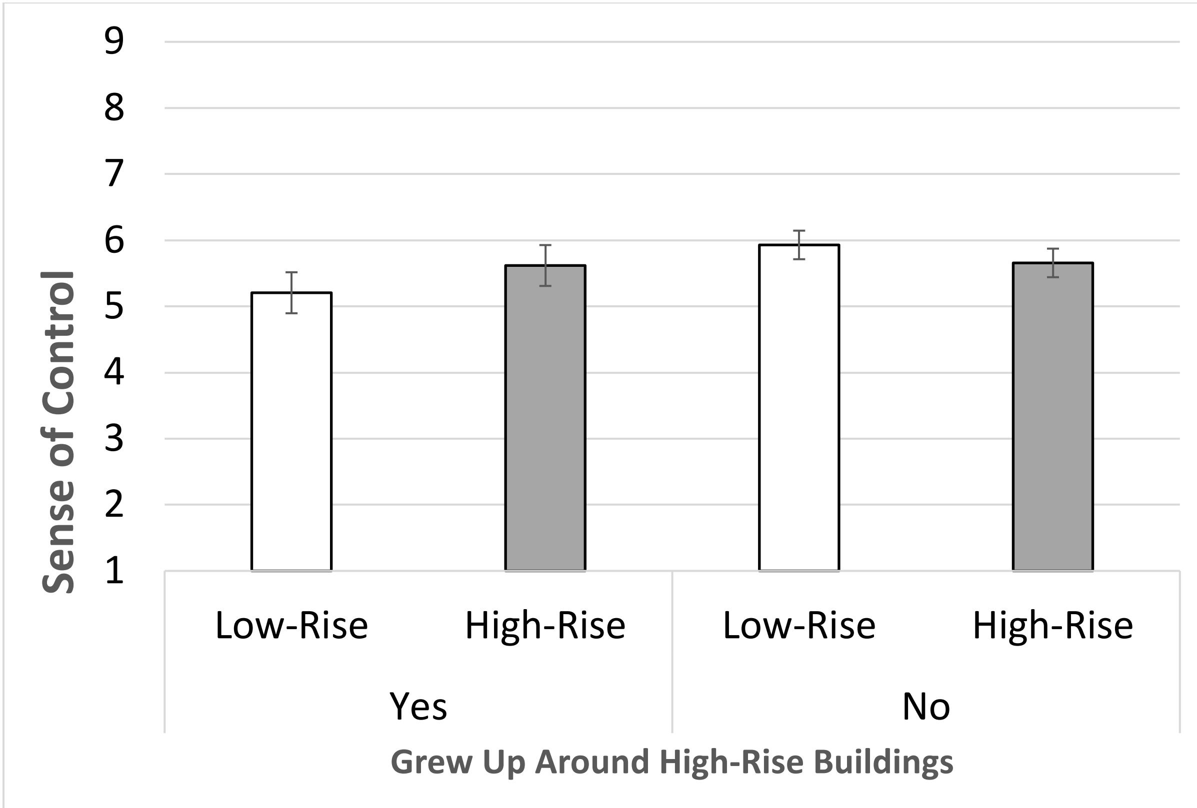

Figure 45. Bar graph showing the influence of building height on sense of control. Error bars represent ± 1 SEM.

A one-way repeated measures ANCOVA was conducted to examine the effects of building height on openness, and no effect was found. A one-way repeated measures MANCOVA was run to examine the effects of distance on the SAM measures of valence, arousal and dominance. There were no significant main effects, however there was a significant interaction between upbringing and building height on sense of control (Figure 45) $F(1,99) = 4.10$, $p = .046$; partial $\eta 2 = .04$. Simple main effects analysis showed a trending effect that could suggest that people who grew up in environments without high-rise buildings feel most in control when exposed to low-rise buildings $F(1,99) = 3.67$, $p = .058$; partial $\eta 2 = .04$.

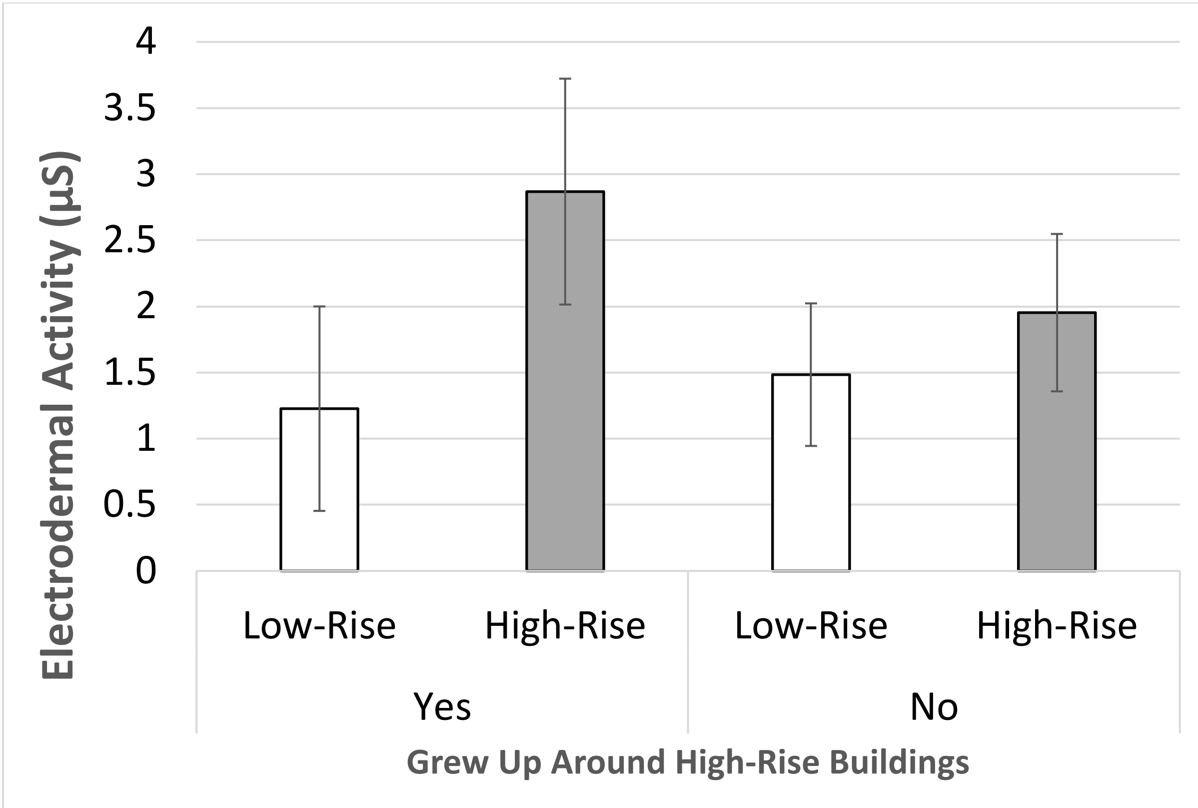

Figure 46. Bar graph showing the influence of building height on electrodermal activity. Error bars represent ± 1 SEM.

Discussion

In *this* study, I was primarily interested in how building height influenced electrodermal activity. I also tested the effects of building height on the SAM measures and openness. Lastly, I was interested in how an individual's exposure to high-rise buildings during their upbringing affected their responses. I found a significant effect of building height on electrodermal activity. This suggests that exposure to tall buildings causes an increase in sympathetic nervous system activity, a physiological indicator of stress. It is possible that the perception of an invasion of space by the high-rise buildings caused the effect. Previous research has shown that the perception of crowdedness produces higher electrodermal activity levels (Aiello et al, 1977; Nicosia et al, 1979). However, those studies involve people, and I was examining the physiological effects of feeling crowded by a building. A virtual reality study by Llobera et al (2010) examining the physiological effect of invasion of space by both humanoid characters and objects, found that the closer an object or humanoid was to an individual, the higher the electrodermal response was. Interestingly, there was no difference found between humanoid characters and objects, which supports the claim that an object, in the case of this study, a building, can cause feelings of an invasion of space. Joye and Dewitte (2016), found that exposure to pictures of high-rise buildings caused behavioural freezing, and suggested negative awe as the mechanism. Behavioural freezing has been shown to be linked to sympathetic nervous system activation, which is what is directly measured by electrodermal activity Lojowska et al., 2015). I did not directly measure behavioural freezing in this study, however, insofar as both electrodermal activity and freezing frequency are elevated by stress - the perception of the invasion of space by the high-rise buildings could be connected to the behavioural freezing response. Sawada (2003), suggests that behavioural freezing is a response to the invasion of space; it is possible that the perception of the invasion of space by high-rise buildings could produce a similar response.

Another key finding of this study is that the effect of exposure to high-rise buildings generalizes across different building exemplars; I exposed participants to 8 different combinations of 5 high-rise buildings (taken from a set of 10) and 8 sets of low-rise buildings (taken from a set of 10). This is in contrast to previous studies were participants were exposed to only one high-rise building and one low-rise building. These results could be extended to the dynamic experience of walking through a city populated with high-rise buildings. Furthermore, that exposure to low-rise buildings yielded a lower electrodermal activity response could suggest the importance of ensuring a diversity of building height in an urban core.

I also found a significant interaction effect of upbringing and building height on sense of control, with people who grew up in environments without skyscrapers to feel most in control when exposed to low-rise buildings. Imamoglu (2000) suggests that familiarity with a setting can alter the appraisal of it, making it seem more pleasant.

A limitation of Study 4 is the absence of an effect of building height on valence, arousal, dominance and openness measures. The absence of the effect could be attributed to the fact that the SAM and openness measure were administered after all five videos of the buildings were shown, instead of after each twenty second video. As mentioned earlier, this approach was taken to ensure the integrity and quality of the electrodermal activity reading. Administering the assessment following each twenty second video would interrupt the electrodermal activity reading. Edelstein and Macago (2012) suggest the benefit of using physiological measures to assess the experience of the built environment is that the measure itself does not interrupt the individual's experience of it, and accordingly does not affect the results of those measures. I attempted to account for this issue in this study. Having participants provide a single rating on their experience of five buildings as opposed to one may have been too abstract a task. A study by Hellhammer and Schubert (2012) examined the stress response to the Trier Social Stress Test (TSST) as measured by both psychological and physiological indicators and found that physiological indicators of stress only correlated with psychological indicators during the stressful experience, but not before or after. This may provide insight into the discordance between the electrodermal activity results and the affect measures, in both Study 1 and this current study. It is important to note that the 360-degree video HMD set up does not allow questions to be asked within the actual environment itself as well; participants are asked to make an appraisal following exposure. At the same time, within dynamic real and virtual environments such assessments can be intrusive, thereby reducing ecological validity (McKendrick et al, 2016). In his treatise titled *Environmental Psychology in the Real World*, Prochansky (1976) suggests environmental psychologists minimize the disturbance of the processes, in this case the experience of the built environment, being measured.

The temporal aspects of environmental psychological research is something that should be considered. Using measures, like the SAM and openness scale give us insight into an individual's state at a specific moment in time. A future direction to explore is how to use a dynamic subjective measure of affect throughout an exposure. Ohno (2018) proposed a dynamic controller with a dial for continuous rating of openness of built environments during locomotion; this method could be adapted to address the emotional experience an individual has as they scan an environment. That said, the previous point about the intrusiveness of subjective measures would be relevant and would need to be considered, depending on the extent of ecological validity researchers are interested in.

Despite these limitations, this study offers insights into the physiological effects of being in the presence of high-rise buildings and suggests exposure to these settings populated by them can increase stress, as measured by electrodermal activity. The implications of this ambient, chronic stress should be taken into account in the design of urban cores.

Chapter 6: General Discussion

Overview

This body of work suggests that exposure to high-rise buildings has measurable psychological impacts. Study 1, which used computer-generated environments and immersive virtual reality, demonstrated that environments populated by high-rise buildings were rated as more oppressive and less open than environments populated by low-rise buildings. Exposure to high-rise buildings also evoked higher levels of electrodermal activity, as compared to exposure to low-rise buildings. Through the use of computer-generated environments, the first study allowed a high level of experimental control on examining the effect of building height, however, it was limited in its generalizability. Therefore, in study 2a, using similar measures, I examined the effects of high-rise buildings a real-world setting in Central London, finding that people rated the high-rise building to be less open and rated themselves to be less happy when exposed to them, as compared to being exposed to the low-rise building. In Study 2b, I took a 360-degree video of the same setting used in study 2a and exposed participants to it using a head mounted device. Participants rated the high-rise building environment to be less open, less friendly and rated themselves to feel less happy and have less sense of control, as compared to low-rise buildings. Study 3 deviated in its methodology slightly from Study 2a. Instead of using 360-degree videos, I used 360-degree photos and examined the effect distance from high-rise buildings had on valence, arousal, sense of control, and openness. Results from Study 3b indicated people are happier, calmer and have a greater sense of control, the further they were from the high-rise. Lastly, Study 5 examined how exposure to multiple high-rise buildings affected electrodermal activity and valence, arousal, sense of control, and openness. Exposure to high-rise buildings yielded higher electrodermal activity. In this study I also examined if growing up in the presence of high-rise building had an effect on any of the measures and found an interaction effect of upbringing and building height on sense of control; participants who did not grow up in the presence of high-rise buildings felt most in control.

Buildings, Body and Brain

"She referred to the high-rise as if it were some kind of huge animate presence, brooding over them."

— J.G. Ballard in his dystopian fiction novel, *High Rise*

There are three major findings of this dissertation that relate to how high-rise buildings make people feel that are summarized in the following points. First, high-rise buildings have a negative influence on emotional state, as measured by subjective affect measures. Second, effects of exposure to high-rise buildings can be assessed using cognitive measures that provide insights on spatial characteristics of the settings. Third, being in the presence of high-rise buildings produces physiological stress, as measured by electrodermal activity. The Probabilistic Model of Aesthetic Response (Nasar, 1994) accounts for the complexity of environmental perception and acknowledges the interaction between affect, perception, and cognition to produce an affective response, which can be measured using a physiological indicator. Accordingly, it would be difficult to discuss the variables examined separately. Therefore, they will be discussed as they are experienced: in relation to each other.

One of the main variables that distinguishes this body of work from the previous, limited research on the psychological impacts of high-rise buildings is the use of an objective physiological measure, namely electrodermal activity. In two of the lab-based studies conducted in this dissertation, which used appropriate electrodermal activity recording equipment which measured from the fingers, I found that high-rise buildings, as compared to low-rise buildings, elicited higher skin conductance levels. Electrodermal activity is associated with increased sympathetic nervous system activity, which controls the stress response (Boucsein, 2012; Dawson et al., 2016). These findings map well onto the findings from this dissertation which demonstrate that people rate themselves as feeling less happy when exposed to high-rise buildings, as compared to exposure to low-rise buildings. Study 3 demonstrated these ratings of unhappiness are amplified the closer an individual is to a high-rise building. How can we explain how building height influences the stress response? Previous research (Asgarzadeh et al., 2012, 2014), exposing participants to pictures high-rise buildings and measuring the effects using subjective measures suggests that they caused feelings of oppressiveness, which has been described as causing a feeling of invasion of space. Invasion of personal space by other people has been shown to cause feelings of distress as measured by subjective measures and electrodermal activity (Kanaga & Flynn,1981). It has also been shown that invasion of space by objects can elicit electrodermal responses (Lloberaet al, 2010), however these objects were not buildings. None of the existing studies examining the psychological impact of being in the presence of high-rise buildings employ physiological methods; all but one solely use subjective measures. In order to understand what is happening at a deeper neurological level, an objective physiological method is required. Joye and Dewitte (2016) used a behavioural measure in their study which involved participants perform a mouse clicking task while looking at pictures of computer-generated and real low-rise and high-rise buildings; they found that people's clicking rates slowed down when they looked at high-rise buildings. The authors suggest that the lower rates of clicking are indicative of behavioural freezing. Behavioural freezing has been shown to be connected to sympathetic nervous system activity and electrodermal activity (Lojowska et al., 2015). What is implied in behavioural freezing is a response to potential threat (Löw et al., 2015). Accordingly, the electrodermal responses I suspect are related to the perception of the invasion of space, can also be linked to threat. In the animal kingdom, predator size is universally associated with threat (Stankowitch & Blumstein, 2005). The association between size and perceived threat also extends to humans (Bailey et al., 1976; Caplan & Goldman, 1981). Schubert (2005) suggests that height is a spatial correlate of power and states, "direct physical experience of vertical differences might be schematized into a perceptual symbol of power" (p. 2). Joye and Verpooten (2013) propose that the human association between size and power is hedged in evolution, and that this association is exploited by monumental architecture; they suggest that the size of buildings can invoke a threat response. This aligns with our findings indicating that people feel less in control the closer they are the high-rise buildings. Furthermore, the shape and orientation of geometric symbols, specifically a downward V, have been shown to trigger a threat response as measured by amygdala activation (Larson et al., 2009). This would suggest that the simple geometry of buildings themselves could potentially play a role in the threat response that is evoked.

In response to looming overhead visual threat, rodents engage in escape and avoidance behaviours (C. G. Ellard, 1993; Colin G. Ellard & Chapman, 1991); these behaviours developed in response to predators that attacked from above and involve the upper visual fields. Liu and Ioannides (2010) found that stimuli presented in upper visual fields deliver fast autonomic response. Generalizations between rodent and human responses is a concern, however a study conducted by Blanchard et al (2001) found a congruence between threat response systems in rodents and humans and suggest that there may be a shared mammalian defense response system. It is possible that the looming quality of high-rise buildings evokes a fight, flight or freeze response, which is controlled by the sympathetic nervous system which produces a measurable electrodermal response, one of the key variables I assessed in this body of work.

High-rise buildings not only evoke threat, but they may also impede the response to it by obfuscating the ability to scan the environment for escape options. Appleton (1975) might have agreed with Blanchard et al's (2001) assertion that we share similar response systems with animals. Appleton (1975) states, "all the evidence points to the fact that the motivation which impels us is of the same kind as that which impels the animals" (p. 67). His observations on how animals, particularly rodents, behave informed his landmark Prospect-Refuge theory, which suggests that across species, there is a universal inclination to survey (prospect) a landscape for affordances, while also being able to hide (refuge) (Appleton, 1975). For humans, environments that optimized for these opportunities were seen as aesthetically desirable. Hildebrand (1999) proposes that these evolved preferences for landscape also apply to the built environment. Prospect requires the ability to see freely, which, in the case of urban environments populated with high-rise buildings, is not possible. The most consistent findings of our study are that high-rise buildings are perceived to be less open. Building height has previously been related to enclosure (Stamps, 2005), and has also been negatively correlated with perceived stress restoration (Lindal & Hartig, 2013). Openness assessed the extent of perceived visual freedom. A study by Stamps (2005) found that building height was associated with ratings of enclosure. Ashihara (1970) suggests that people can feel “claustrophobic” when surrounded by high-rise buildings. A study by Stamps (2005) found that building height was associated with ratings of enclosure. Spatial enclosure has very recently been suggested as one of the most powerful influences on psychological responses to the built environment (Coburn et al., 2020). Vartanian et al (2015) defined perceived enclosure as "the degree of perceived visual and locomotive permeability" (p. 11). In their study, they examined the neural correlates of perceived enclosure and found it to be correlated with activation of the anterior cingulate cortex, which is implicated in the fear response (Vartanian et al, 2015). The authors suggest that this fear response is in relation to perceived enclosure and an inability to escape. The anterior cingulate cortex is directly involved in the neural pathway for the electrodermal response (Boucsein, 2012). In his book *The Psychology of Fear and Stress*, Gray (1987) suggests that a response to fear stimuli activates a behavioural inhibition system, which has two distinct roles. The first role is the inhibition of behaviour, in other words, behavioural freezing. The second role involves the facilitation of a comprehensive appraisal of the surrounding environment. Taking these roles into account, it would seem plausible that the electrodermal response elicited when in the presence of high-rise buildings could be an indicator of stress, specifically freezing and an assessment of escapability. Electrodermal activity has been shown to be an indicator of other variables relevant to environmental perception, including informational processing. Accordingly, as Boucsein (2012) recommends, other subjective variables, like the ones used in this dissertation, are necessary to obtain a complete understanding of the emotional experience. This also aligns with Nasar's Probabilistic Model of Aesthetic Experience, which implies affective, cognitive and physiological components of the aesthetic response.

The electrodermal response may have implications on the experience of personal space crowding, the threat of a looming object, and/or an individual's ability to survey their environment. It is unknown which variable, or combination of them could be involved. Furthermore, electrodermal activity can serve as approximation of sympathetic nervous system activity, however we cannot know for certain how these environments influence brain activity. To properly assess the question, future research could apply virtual reality to adequately simulate the environments while using more refined neuroimaging techniques like electroencephalography, which has been shown to be able to record ACC activation. However, EEG is limited in its localization abilities, which would further require the use of functional magnetic resonance imaging. As of yet, using virtual reality in fMRI is still not an easy endeavour.

Another variable to consider involve the influence of these environments on psychoacoustics. Environments populated by high-rise buildings are suggested to cause a noise canyon effect; the implications of noise on the emotional experience of being in these settings cannot be ignored (Li & Lai, 2009). These future directions, however, require a reflection on methodology and ecological validity.

A Method to the Madness

"There is a central quality which is the root criterion of life and spirit in a person, a town, a building, or a wilderness. This quality is objective and precise, but it cannot be named."

- Christopher Alexander

The final contribution of this body of work involves how exactly one goes about studying complex ambient stressors like exposure to high-rise buildings in an ecologically valid manner. Teasing apart the effects of single variables in the complicated sensory miasma of the urban environment is not a simple task. Considering ecological validity, the way environmental psychological research is conducted should be driven by the questions asked (Evans, 1984). According to Sreufert and Swezey (1982, p. 7), "Simulation represents an ongoing process in which persons interact continually with an active complex environment. Responding to paper and pencil questions on how one would respond to some environmental change, how one would vote if selected for a jury and so forth does represent experimentation. It does not, however, represent simulation research." If the researcher is interested in physiological variables, attempts should be made to ensure the physiological signals are not interrupted by the administration of subjective measures. Arguably, subjective measures should be administered following exposure, but it should also be taken into consideration that the effect of exposure, as measured by these instruments, may be diminished (Reinhardt et al, 2004). Considerations should be made on the use of retrospective measures in studies that involve virtual reality, as they require participants to complete them when they are removed from their environments, sitting in a lab, which is a completely different context. An advantage of doing real world research is that these questions can be asked following "exposure", but the participants will still be in the environment. Another learning from this dissertation is that environmental psychological research, particularly research that examines emotion, should be done under the guise of deception, due to the risk of priming. This dissertation, specifically, focused on the exposure to high-rise buildings as an ambient stressor. Ambient stressors are environmental stressors that are not at the forefront of awareness, but still have a long-term effect on wellbeing (Campbell, 1981). I was more interested in understanding how high-rise buildings impacted people emotionally when they were not aware of it, as this is the experience of most city dwellers. It is unlikely people actively reflect on the stressful experience of being in the presence of high-rise buildings; accordingly, I wanted to examine these effects with that assumption. Cognitive appraisals of the environment, such as openness, however, may be less susceptible to the Hawthorne effect.

In addition to reflecting on the variables examined, it is also important to consider how participants are exposed the environments we are interested in studying. Pictures may be a good first step, however they cannot accurately represent an experience of the built environment. JJ

Gibson, a key figure in the development of the field of environmental perception stated the following:

> "The visual world is a kind of experience that does not correspond to anything, not any possible picture, not any motion picture, and not even any "panoramic" motion picture. The visual world is not a projection of the ecological world. How could it be? The visual world is the outcome of the picking up of invariant information in an ambient optic array by an exploring visual system, and the awareness of the observer's own body in the world is a part of the experience" (Gibson, 2014, p 297).

I would suggest that the most accurate simulation of the visual world involves the use of 360-degree video presented in an HMD. Our findings indicate people respond similarly to 360-degree video environments of real-world location. This methodology should be considered, where feasible, for future environmental psychological research on the impacts of the built environment. A limitation, however, is that this methodology is limited to existing designs, which computer-generated environments can address. One potential avenue to experience computer-generated architecture in a real-world setting would be to marry augmented reality with 360-degree video, however the technology to do so does not currently exist.

Implications

Future research in this area should extend beyond the affective impact of being in the presence of high-rise buildings. How does how someone feels in these environments influence how they behave in them? Proxemic behaviour, how people negotiate the space they keep between themselves, others, and facets of the built environment, would be a natural next step. If people find these settings to be aversive, what implications does it have on how they behave towards others who occupy these spaces. Or, perhaps of more interest, do people avoid these settings in general? What implications could this have on economic activity?

When considering how we will continue to build cities of the future, it may serve us to refer to wisdom of the past, like Vitruvius, who emphasized the equal importance of structural integrity, function, and visual experience of a building. Some would argue we have not evolved much as humans, since the time of Vitruvius, but our capacity to build has evolved significantly. This isn't to say that ancient humans have never been in the presence of large physical structures, like gothic churches or pyramids in Egypt. Discussing the sublime, Cochrane (2012) suggests, "we can imaginatively identify with skyscrapers or pyramids in the same way as we can with mountains, since the claim is that we identify with properties (such as largeness) that these objects have in common" (p.143). Edward Burke (1870), described the emotional experience of the sublime to be one that simultaneously elicits terror and wonder. It's important to note that ancient monuments were usually singular and the focus of the settlements they were in; in the modern metropolis we are surrounded by high-rise buildings. With modern technologies, the sky is literally the limit. Should there be a limit? Should we build our cities to a human scale? Colombian architect Simón Vélez refers to human scale as "an architecture that acknowledges limits." Vélez, who is notable for his work building bamboo buildings, further states, "concrete functions as an amplifier for building materials...it creates the possibility to endlessly challenge and break the human and natural scale of things." Results from our study indicate that habituation to these environments does not mitigate the psychological impacts of being in them. It's important to consider what a future where the skies are dominated by high-rise buildings would be like. Auerbach and Wan (2020) used a modelling technique called extreme value theory to predict the number of skyscrapers there would be by the year 2050. Currently there are approximately 800 skyscrapers per billion people; by 2050, it is estimated there will be 6,800 skyscrapers per billion people, and the tallest will be 50% taller (Auerbach and Wan, 2020). The United Nations (2015) predicts that 68% of the world's population will live in cities by the year 2050. The predicted influx of people to urban centres in concert with a projected 850% increase in skyscrapers suggests that the experience of crowding, by both people and the built environment could be a real concern. Accordingly, the process of densification should not be solely about how many people can be fit into a small footprint of land; different methods of densification should be considered that take into account the psychological experiences of living in and around buildings. Bharne (2011) proposes the concept of blended density, where instead of concentrating all density in high-rise building, it is distributed amongst a mixture of low rise, mid rise and high rise buildings. Berghauser and Haupt (2005) acknowledge these complexities and propose a quantitative methodology called *Spacecraft* to assess urban densification that takes into account intensity (ratio of floor space in a building to the land it occupies), compactness, building height, and open space ratio. The *Spacecraft* process computes what they call a "spatial fingerprint" to help practitioners reflect on the different spatial aspects of a building project. Their methodology does not involve a psychological component, however, the findings from this study on building height and openness could be overlaid to enhance qualitative, experiential aspects of a potential project.

Even considering alternate methods of densification, I do not believe that cities should, or will, stop building upward. Attention should be paid to the negative space in cities; spaces with an absence of built structures and the roles they can play in mitigation and restoration. Much focus has been placed on access to urban green space for its known benefits to wellbeing (Mitchell, & Popham, 2012; De Vries, Verheij, & Groenewegen, 2003; Kardan et al, 2015). I do not wish to go into the psychology of the restorative effects of green space as it pertains to the "greenness", but rather want to suggest that green space in cities can also be conceptualized as “open space”, and that this openness may provide restorative benefits. Open space is considered to be essential to provide relief to urban residents in dense, built up environments (Ishikawa et al, 1998); open spaces can provide reprieve from the effects of being in the constant presence of high-rise buildings. development of open spaces of various scales will help offset the effects of neighborhoods increasingly filled with tall buildings" (p. 8) The term “open space” can refer to green space, but also the public squares found in our cities, such as Times Square in New York City, Trafalgar Square in London, and Dundas Square in Toronto. In his book *Image of the City*, Kevin Lynch (1963, p. 3) states that "open space is an outdoor area...which is open to the freely-chosen and spontaneous activity, movement, or visual exploration.” Wilkinson (1989) criticizes modern urban planning in not appreciating the value of open space, and suggests open space is seen by planners as “non-functional embellishments” and encourages practitioners to consider viewing open spaces as tools to make urban environments more inhabitable. It’s important to note that open public spaces in cities are under threat; privately owned buildings often have “public space” adjacent to them, however these spaces are often policed by security hired by the corporations who own these buildings. I experienced the consequences of this firsthand while taking a 360-degree video of high-rise building for Study 4. I was in what I believed was a public space and was harassed by two security guards and ultimately was told to leave the property because it was a privately-owned space (BlogTo, 2019). I later clarified this was not the case, however these blurred lines need to be examined. I share this experience to not only reaffirm the importance of truly public open space, but also to highlight other detrimental effects high-rise buildings can have on how we experience cities.

There are two general offerings contained within this dissertation. First, it highlights the importance of applying a psychological lens to the way we urbanize our cities; it is crucial to intentionally build our cities and prioritize wellbeing as we move forward. Second, it proposes five methodologies that can be used to examine how the built environment affects us psychologically and physiologically. While this dissertation dealt in understanding the psychological impacts of high-rise buildings, the methodologies can be extended to other built environments.

It is my hope that this work not only informs practitioners who work in city building, but that it also serves researchers who belong to this budding and fascinating field of study. Despite the seemingly dark future ahead for cities, it is my belief that a psychological approach to urban design will ensure the future is bright, or, at least tolerable.

References

Aiello, J. R., DeRisi, D. T., Epstein, Y. M., & Karlin, R. A. (1977). Crowding and the Role of Interpersonal Distance Preference. *Sociometry*, *40*(3), 271. https://doi.org/10.2307/3033534

Ali, M. M., & Al-Kodmany, K. (2012). Tall buildings and Urban habitat of the 21st century: A global perspective. *Buildings*, *2*(4), 384–423. https://doi.org/10.3390/buildings2040384

Appert, M., & Montes, C. (2015). Skyscrapers and the redrawing of the London skyline: A case of territorialisation through landscape control. *Articulo - Journal of Urban Research*, *2015*(Spec. Issue 7). https://doi.org/10.4000/articulo.2784

Asgarzadeh, M., Koga, T., Hirate, K., Farvid, M., & Lusk, A. (2014). Investigating oppressiveness and spaciousness in relation to building, trees, sky and ground surface: A study in Tokyo. *Landscape and Urban Planning*, *131*, 36–41. https://doi.org/10.1016/j.landurbplan.2014.07.011

Asgarzadeh, M., Lusk, A., Koga, T., & Hirate, K. (2012). Measuring oppressiveness of streetscapes. *Landscape and Urban Planning*, *107*(1), 1–11. https://doi.org/10.1016/j.landurbplan.2012.04.001

Ashihara, Y. (1981). Exterior design in architecture. Van Nostrand Reinhold Company.

Ataov, A. (1998). Environmental Aesthetics. *Journal of Planning Literature*, *13*(2), 239–257. https://doi.org/10.1177/088541229801300206

Auerbach, J., & Wan, P. (2020). Forecasting the urban skyline with extreme value theory. *International Journal of Forecasting*. https://doi.org/10.1016/j.ijforecast.2019.09.004

Baddeley, A. (2013). Finding the bloody horse. In L. W. Poon, D. C. Rubin, & B. A. Wilson (Eds.), *Everyday Cognition in Adulthood and Late Life* (pp. 104–115). Cambridge Univ. Press. https://doi.org/10.1017/cbo9780511759390.009

Bailey, K. G., Caffrey, J. V., & Hartnett, J. J. (1976). Body Size as Implied Threat: Effects on Personal Space and Person Perception. *Perceptual and Motor Skills*, *43*(1), 223–230. https://doi.org/10.2466/pms.1976.43.1.223

Barr, J. (2012). Skyscraper Height. *Journal of Real Estate Finance and Economics*, *45*(3), 723–753. https://doi.org/10.1007/s11146-010-9274-z

Barton, K. R., Valtchanov, D., & Ellard, C. (2014). Seeing Beyond Your Visual Field: The Influence of Spatial Topology and Visual Field on Navigation Performance. *Environment and Behavior*, *46*(4), 507–529. https://doi.org/10.1177/0013916512466094

Baum, A., Singer, J. E., & Baum, C. S. (1982). Stress and the environment. *Environmental Stress*, *37*(1), 15–44.

Beil, K., & Hanes, D. (2013). The influence of urban natural and built environments on physiological and psychological measures of stress- A pilot study. *International Journal of Environmental Research and Public Health*, *10*(4), 1250–1267. https://doi.org/10.3390/ijerph10041250

Berghauser, M., & Haupt, P. (2005). The Spacemate: Density and the Typomorphology of the Urban Fabric. In *Urbanism Laboratory for Cities and Regions Progress of Research Issues in Urbanism 2007* (Vol. 4, Issue 4, pp. 55–68).

Bernstein, K. T., Galea, S., Ahern, J., Tracy, M., & Vlahov, D. (2007). The built environment and alcohol consumption in urban neighborhoods. *Drug and Alcohol Dependence*, *91*(2–3), 244–252. https://doi.org/10.1016/j.drugalcdep.2007.06.006

Bettencourt, L., & West, G. (2010). A unified theory of urban living. *Nature*, *467*(7318), 912–913. https://doi.org/10.1038/467912a

Bharne, V. (2011). Humanizing high-rise urbanism: Design strategies and planning tools. *CTBUH Journal*, *4*, 18–23.

Black, D., O'Loughlin, K., Kendig, H., & Wilson, L. (2012). Cities, environmental stressors, ageing and chronic disease. *Australasian Journal on Ageing*, *31*(3), 147–151. https://doi.org/10.1111/j.1741-6612.2011.00552.x

Blanchard, D.C., Hynd, A. L., Minke, K. A., Minemoto, T., & Blanchard, R. J. (2001). Human defensive behaviors to threat scenarios show parallels to fear- and anxiety-related defense patterns of non-human mammals. *Neuroscience and Biobehavioral Reviews*, *25*(7–8), 761–770. https://doi.org/10.1016/S0149-7634(01)00056-2

BlogTO. (2019). A security guard in Toronto just told someone he couldn't take a photo of a building. Retrieved from: https://www.blogto.com/city/2019/07/security-guard-toronto-photo-building/

Bokharaei, S., & Nasar, J. L. (2016). Perceived Spaciousness and Preference in Sequential Experience. *Human Factors*, *58*(7), 1069–1081. https://doi.org/10.1177/0018720816650068

Boucsein, W. (2012). *Electrodermal Activity*. Springer US. https://doi.org/10.1007/978-1-4614-1126-0

Bower, I., Tucker, R., & Enticott, P. G. (2019). Impact of built environment design on emotion measured via neurophysiological correlates and subjective indicators: A systematic review. *Journal of Environmental Psychology*, *66*, 101344. https://doi.org/10.1016/j.jenvp.2019.101344

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*(1), 49–59. https://doi.org/10.1016/0005-7916(94)90063-9

Brehmer, B., & Dörner, D. (1993). Experiments with computer-simulated microworlds: Escaping both the narrow straits of the laboratory and the deep blue sea of the field study. *Computers in Human Behavior*, *9*(2–3), 171–184. https://doi.org/10.1016/0747-5632(93)90005-D

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist*, *32*(7), 513–531. https://doi.org/10.1037/0003-066x.32.7.513

Campbell, J. M. (1983). Ambient stressors. *Environment and Behavior*, *15*(3), 355–380. https://doi.org/10.1177/0013916583153005

Caplan, M. E., & Goldman, M. (1981). Personal space violations as a function of height. *Journal of Social Psychology*, *114*(2), 167–171. https://doi.org/10.1080/00224545.1981.9922746

Centre for Addiction and Mental Health. (2012). Mental Illness and Addictions: Facts and Statistics. Retrieved from: http://www.camh.ca/en/hospital/about_camh/newsroom/for_reporters/Pages/addictionmentalhealthstatistics.aspx

Charney, I. (2007). The politics of design: Architecture, tall buildings and the skyline of central London. *Area*, *39*(2), 195–205. https://doi.org/10.1111/j.1475-4762.2007.00741.x

City of London. (2020). Policy D8: Tall Buildings. In *Draft New London* Plan. Retrieved from https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/draft-new-london-plan/chapter-3-design/policy-d8-tall-buildings

Coburn, A., Vartanian, O., Kenett, Y. N., Nadal, M., Hartung, F., Hayn-Leichsenring, G., Navarrete, G., González-Mora, J. L., & Chatterjee, A. (2020). Psychological and neural responses to architectural interiors. *Cortex*, *126*, 217–241. https://doi.org/10.1016/j.cortex.2020.01.009

Cochrane, T. (2012). The emotional experience of the sublime. *Canadian Journal of Philosophy*, *42*(2), 125–148. https://doi.org/10.1353/cjp.2012.0003

Coeterier, J. F. (1994). Cues for the perception of the size of space in landscapes. *Journal of Environmental Management*, *42*(4), 333–347. https://doi.org/10.1006/jema.1994.1076

Council on Tall Buildings and Urban Habitats (2018). CBTUH Year in Review: Tall Trends of 2018. Retrieved from: http://www.skyscrapercenter.com/research/CTBUH_ResearchReport_2018YearInReview.pdf

Craggs, D. (2018). Skyscraper development and the dynamics of crisis: The new london skyline and spatial recapitalization. *Built Environment*, *43*(4), 500–519. https://doi.org/10.2148/benv.43.4.500

Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *351*(1346), 1413–1420. https://doi.org/10.1098/rstb.1996.0125

Dawson, M. E., Schell, A. M., & Filion, D. L. (2016). The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, & and (Eds.), *Handbook of Psychophysiology, Fourth Edition* (pp. 217–243). https://doi.org/10.1017/9781107415782.010

de Kort, Y. A. W., Meijnders, A. L., Sponselee, A. A. G., & IJsselsteijn, W. A. (2006). What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of Environmental Psychology*, *26*(4), 309–320. https://doi.org/10.1016/j.jenvp.2006.09.001

de Vries, S., Verheij, R. A., Groenewegen, P. P., & Spreeuwenberg, P. (2003). Natural environments - Healthy environments? An exploratory analysis of the relationship between greenspace and health. *Environment and Planning A*, *35*(10), 1717–1731. https://doi.org/10.1068/a35111

Edelstein, E. A., & Macagno, E. (2012). Form follows function: Bridging neuroscience and architecture. In *Springer Optimization and Its Applications* (Vol. 56, pp. 27–41). Springer. https://doi.org/10.1007/978-1-4419-0745-5_3

Ehgoetz Martens, K. A., Ellard, C. G., & Almeida, Q. J. (2014). Does manipulating the speed of visual flow in virtual reality change distance estimation while walking in Parkinson's disease? *Experimental Brain Research*, *233*(3), 787–795. https://doi.org/10.1007/s00221-014-4154-z

Ellard, C. G. (1993). Organization of escape movements from overhead threats in the Mongolian gerbil (Meriones unguiculatus). *Journal of Comparative Psychology*, *107*(3), 242–249. https://doi.org/10.1037/0735-7036.107.3.242

Ellard, C. G., & Chapman, D. G. (1991). The effects of posterior cortical lesions on responses to visual threats in the Mongolian gerbil (Meriones unguiculatus). *Behavioural Brain Research*, *44*(2), 163–167. https://doi.org/10.1016/S0166-4328(05)80021-X

Ellard, C. (2015). *Places of the Heart: The Psychogeography of Everyday Life*. Bellevue Literary Press.

Evans, G. W. (Ed.). (1984). Environmental Stress. Cambridge University Press.

Evans, G. W., & McCoy, J. M. (1998). When buildings don't work: The role of architecture in human health. *Journal of Environmental Psychology*, *18*(1), 85–94. https://doi.org/10.1006/jevp.1998.0089

Evans, G. W. (2003). The built environment and mental health. *Journal of Urban Health : Bulletin of the New York Academy of Medicine*, *80*(4), 536–555. https://doi.org/10.1093/jurban/jtg063

Galea, S., Ahern, J., Rudenstine, S., Wallace, Z., & Vlahov, D. (2005). Urban built environment and depression: A multilevel analysis. *Journal of Epidemiology and Community Health*, *59*(10), 822–827. https://doi.org/10.1136/jech.2005.033084

Gao, M., Ahern, J., & Koshland, C. P. (2016). Perceived built environment and health-related quality of life in four types of neighborhoods in Xi'an, China. *Health and Place*, *39*, 110–115. https://doi.org/10.1016/j.healthplace.2016.03.008

Gibson, J. J. (2014). *The ecological approach to visual perception: classic edition*. Psychology Press.

Goldhagen, S. (2017). *Welcome to your world*. Harper. New York.

Gorus, G. (n.d.). *Colombian top architect Simón Vélez calls for buildings on a human scale | MO*. Mondiaal Nieuws*. https://www.mo.be/en/article/colombian-top-architect-simon-velez-calls-buildings-human-scale

Gray, J. A. (1987). *The psychology of fear and stress* (Vol. 5). CUP Archive.

Heath, G. W., Brownson, R. C., Kruger, J., Miles, R., Powell, K. E., Ramsey, L. T., & __. (2016). The Effectiveness of Urban Design and Land Use and Transport Policies and Practices to Increase Physical Activity: A Systematic Review. *Journal of Physical Activity and Health*, *3*(s1), S55–S76. https://doi.org/10.1123/jpah.3.s1.s55

Higuera-Trujillo, J. L., López-Tarruella Maldonado, J., & Llinares Millán, C. (2017). Psychological and physiological human responses to simulated and real environments: A comparison between Photographs, 360° Panoramas, and Virtual Reality. *Applied Ergonomics*, *65*, 398–409. https://doi.org/10.1016/j.apergo.2017.05.006

Hildebrant, G. (1999). *Origins of Architectural Pleasure*. University of California Press. https://doi.org/9780520215054

Hur, M., Nasar, J. L., & Chun, B. (2010). Neighborhood satisfaction, physical and perceived naturalness and openness. *Journal of Environmental Psychology*, *30*(1), 52–59. https://doi.org/10.1016/j.jenvp.2009.05.005

Imamoglu, Ç. (2000). Complexity, liking and familiarity: Architecture and non-architecture Turkish students' assessments of traditional and modern house facades. *Journal of Environmental Psychology*, *20*(1), 5–16. https://doi.org/10.1006/jevp.1999.0155

Ishikawa, T., Okabe, A., Sadahiro, Y., & Kakumoto, S. (1998). An experimental analysis of the perception of the area of an open space using 3-D stereo dynamic graphics. *Environment and Behavior*, *30*(2), 216–234. https://doi.org/10.1177/0013916598302005

Jorgensen, L. J., Ellis, G. D., & Ruddell, E. (2013). Fear Perceptions in Public Parks. *Environment and Behavior*, *45*(7), 803–820. https://doi.org/10.1177/0013916512446334

Joye, Y., & Dewitte, S. (2016). Up speeds you down. Awe-evoking monumental buildings trigger behavioral and perceived freezing. *Journal of Environmental Psychology*, *47*, 112–125. https://doi.org/10.1016/j.jenvp.2016.05.001

Joye, Y., & Verpooten, J. (2013). An exploration of the functions of religious monumental architecture from a Darwinian perspective. *Review of General Psychology*, *17*(1), 53–68. https://doi.org/10.1037/a0029920

Kanaga, K. R., & Flynn, M. (1981). The Relationship Between Invasion of Personal Space and Stress. *Human Relations*, *34*(3), 239–248. https://doi.org/10.1177/001872678103400305

Kaplan, R., & Kaplan, S. (1989). The experience of nature: a psychological perspective. In *The experience of nature: a psychological perspective*. CUP Archive. https://doi.org/10.1097/00005053-199111000-00012

Kaplan, R., Kaplan, S., & Brown, T. (1989). Environmental Preference: A Comparison of Four Domains of Predictors. *Environment and Behavior*, *21*(5), 509–530. https://doi.org/10.1177/0013916589215001

Karakas, T., & Yildiz, D. (2020). Exploring the influence of the built environment on human experience through a neuroscience approach: A systematic review. *Frontiers of Architectural Research*, *9*(1), 236–247. https://doi.org/10.1016/j.foar.2019.10.005

Kardan, O., Gozdyra, P., Misic, B., Moola, F., Palmer, L. J., Paus, T., & Berman, M. G. (2015). Neighborhood greenspace and health in a large urban center. *Scientific Reports*, *5*, 11610. https://doi.org/10.1038/srep11610

Lazarus, R. (1993). From Psychological Stress to the Emotions: A History of Changing Outlooks. *Annual Review of Psychology*, *44*(1), 1–21. https://doi.org/10.1146/annurev.psych.44.1.1

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., Wüst, S., Pruessner, J. C., Rietschel, M., Deuschle, M., & Meyer-Lindenberg, A. (2011). City living and urban upbringing affect neural social stress processing in humans. *Nature*, *474*(7352), 498–501. https://doi.org/10.1038/nature10190

Li, K. M., & Lai, C. Y. C. (2009). A note on noise propagation in street canyons. *The Journal of the Acoustical Society of America*, *126*(2), 644–655. https://doi.org/10.1121/1.3158599

Lindal, P. J., & Hartig, T. (2013). Architectural variation, building height, and the restorative quality of urban residential streetscapes. *Journal of Environmental Psychology*, *33*, 26–36. https://doi.org/10.1016/j.jenvp.2012.09.003

Liu, L., & Ioannides, A. A. (2010). Emotion separation is completed early and it depends on visual field presentation. *PLoS ONE*, *5*(3). https://doi.org/10.1371/journal.pone.0009790

Lojowska, M., Gladwin, T. E., Hermans, E. J., & Roelofs, K. (2015). Freezing promotes perception of coarse visual features. *Journal of Experimental Psychology: General*, *144*(6), 1080–1088. https://doi.org/10.1037/xge0000117

Löw, A., Weymar, M., & Hamm, A. O. (2015). When Threat Is Near, Get Out of Here: Dynamics of Defensive Behavior During Freezing and Active Avoidance. *Psychological Science*, *26*(11), 1706–1716. https://doi.org/10.1177/0956797615597332

Lynch, K. (1964). *Image of the city* (1st ed.). MIT Press.

Mandler, G. (1975). *Mind and Emotion*. Wiley.

McEwen, B. S. (1998). Stress: Allostasis and allostatic load. *Ann N Y Acad Sci*, *840*(1), 33.

McKendrick, R., Parasuraman, R., Murtza, R., Formwalt, A., Baccus, W., Paczynski, M., & Ayaz, H. (2016). Into the wild: Neuroergonomic differentiation of hand-held and augmented reality wearable displays during outdoor navigation with functional near infrared spectroscopy. *Frontiers in Human Neuroscience*, *10*(MAY2016), 216. https://doi.org/10.3389/fnhum.2016.00216

Mehrabian, A., & Russell, J. A. (1974). *An Approach to Environmental Psychology*. the MIT Press.

Mitchell, R., & Popham, F. (2007). Greenspace, urbanity and health: Relationships in England. *Journal of Epidemiology and Community Health*, *61*(8), 681–683. https://doi.org/10.1136/jech.2006.053553

Montgomery, C. (2013). *Happy City: Transforming Our Lives Through Urban Design*. Doubleday Canada.

Morgan, M. H. (1914). The ten books on architecture. Cambridge, Massachusetts: Harvard University Press.

Nasar, J. L. (1994). Urban Design Aesthetics: The Evaluative Qualities of Building Exteriors. *Environment and Behavior*, *26*(3), 377–401. https://doi.org/10.1177/001391659402600305

New London Architecture (2015). London Tall Buildings Survey 2015. Retrieved from: https://www.newlondonarchitecture.org/docs/tall_bldgs_survey_2015.pdf

New London Architecture (2020). London Tall Buildings Survey 2020. Retrieved from: https://www.newlondonarchitecture.org/docs/tall_bldgs_survey_2020.pdf

Negami, H. R., Mazumder, R., Reardon, M., & Ellard, C. G. (2018). Field analysis of psychological effects of urban design: a case study in Vancouver. *Cities & Health*, *2*(2), 106–115. https://doi.org/10.1080/23748834.2018.1548257

Nicosia, G. J., Hyman, D., Karlin, R. A., Estein, Y. M., & Aiello, J. R. (1979). Effects of Bodily Contact on Reactions to Crowding. *Journal of Applied Social Psychology*, *9*(6), 508–523. https://doi.org/10.1111/j.1559-1816.1979.tb00812.x

Parakh, J., Gabel, J. & Safarik, D. (2017) The Space Between: Urban Places, Public Spaces & Tall Buildings: An output of the CTBUH Urban Habitat / Urban Design Committee. Chicago: Council on Tall Buildings and Urban Habitat.

Parker, M. (2015). Vertical capitalism: Skyscrapers and organization. *Culture and Organization*, *21*(3), 217–234. https://doi.org/10.1080/14759551.2013.845566

Parsons, T. D. (2015). Virtual reality for enhanced ecological validity and experimental control in the clinical, affective and social neurosciences. *Frontiers in Human Neuroscience*, *9*(DEC), 660. https://doi.org/10.3389/fnhum.2015.00660

Payne, A. F. H., Schell, A. M., & Dawson, M. E. (2016). Lapses in skin conductance responding across anatomical sites: Comparison of fingers, feet, forehead, and wrist. *Psychophysiology*, *53*(7), 1084–1092. https://doi.org/10.1111/psyp.12643

Peen, J., Schoevers, R. A., Beekman, A. T., & Dekker, J. (2010). The current status of urban-rural differences in psychiatric disorders. *Acta Psychiatrica Scandinavica*, *121*(2), 84–93. https://doi.org/10.1111/j.1600-0447.2009.01438.x

Purcell, A. T., & Nasar, J. L. (1992). Experiencing other people's houses: a model of similarities and differences in environmental experience. *Journal of Environmental Psychology*, *12*(3), 199–211. https://doi.org/10.1016/S0272-4944(05)80135-5

Purcell, A. T. (1986). Environmental perception and affect: A Schema Discrepancy Model. *Environment and Behavior*, *18*(1), 3–30. https://doi.org/10.1177/0013916586181001

Quirin, M., Kazén, M., & Kuhl, J. (2009). When Nonsense Sounds Happy or Helpless: The Implicit Positive and Negative Affect Test (IPANAT). *Journal of Personality and Social Psychology*, *97*(3), 500–516. https://doi.org/10.1037/a0016063

Reinhardt, T., Schmahl, C., Wüst, S., & Bohus, M. (2012). Salivary cortisol, heart rate, electrodermal activity and subjective stress responses to the Mannheim Multicomponent Stress Test (MMST). *Psychiatry Research*, *198*(1), 106–111. https://doi.org/10.1016/j.psychres.2011.12.009

Rohrmann, B., & Bishop, I. (2002). Subjective responses to computer simulations of urban environments. *Journal of Environmental Psychology*, *22*(4), 319–331. https://doi.org/10.1006/jevp.2001.0206

Rubin, D. C. (2013). Issues of regularity and control: Confessions of a regularity freak. In L. W. Poon, D. C. Rubin, B. A. Wilson, & B. C. Wilson (Eds.), *Everyday Cognition in Adulthood and Late Life* (pp. 84–103). Cambridge University Press. https://doi.org/10.1017/cbo9780511759390.008

Saegert, S., & Winkel, G. H. (1990). Environmental Psychology. *Annual Review of Psychology*, *41*(1), 441–477. https://doi.org/10.1146/annurev.ps.41.020190.002301

Saga, K. (2002). Structure and function of human sweat glands studied with histochemistry and cytochemistry. *Progress in Histochemistry and Cytochemistry*, *37*(4), 323–386. https://doi.org/10.1016/S0079-6336(02)80005-5

Sawada, Y. (2003). Blood pressure and heart rate responses to an intrusion on personal space. *Japanese Psychological Research*, *45*(2), 115–121. https://doi.org/10.1111/1468-5884.t01-2-00039

Schertz, K. E., & Berman, M. G. (2019). Understanding Nature and Its Cognitive Benefits. *Current Directions in Psychological Science*, *28*(5), 496–502. https://doi.org/10.1177/0963721419854100

Schmuckler, M. A. (2001). What is Ecological Validity? A Dimensional Analysis. *Infancy*, *2*(4), 419–436. https://doi.org/10.1207/S15327078IN0204_02

Schubert, T. W. (2005). Your highness: Vertical positions as perceptual symbols of power. In *Journal of Personality and Social Psychology* (Vol. 89, Issue 1, pp. 1–21). https://doi.org/10.1037/0022-3514.89.1.1

Stamps, A. E. (2005). Visual permeability, locomotive permeability, safety, and enclosure. *Environment and Behavior*, *37*(5), 587–619. https://doi.org/10.1177/0013916505276741

Stamps A. E. (2010). Use of static and dynamic media to simulate environments to: A meta-analysis. *Perceptual and Motor Skills*, *111*, 355–364. https://doi.org/10.2466/22.24.27.PMS.111.5.355-364

Stamps, A. E., & Smith, S. (2002). Environmental enclosure in urban settings. *Environment and Behavior*, *34*(6), 781–794. https://doi.org/10.1177/001391602237246

Stankowich, T., & Blumstein, D. T. (2005). Fear in animals: A meta-analysis and review of risk assessment. In *Proceedings of the Royal Society B: Biological Sciences* (Vol. 272, Issue 1581, pp. 2627–2634). Royal Society. https://doi.org/10.1098/rspb.2005.3251

Statistics Canada. (2016). Population, urban and rural, by province and territory (Ontario). In *Summary Tables*. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo62g-eng.htm

Stemmler, G. (1987). Standardization Within Subjects: A Critique of Ben-Shakhar's Conclusions. *Psychophysiology*, *24*(2), 243–246. https://doi.org/10.1111/j.1469-8986.1987.tb00286.x

Streufert, S., & Swezey, R.W. (1985). Simulation and related research methods in environmental psychology. In Singer J., & Baum, A. (Eds.). *Advances in environmental psychology*, 5: pp 99-117.

Thiel, P., Harrison, E. D., & Alden, R. S. (1986). The perception of spatial enclosure as a function of the position of architectural surfaces. *Environment and Behavior*, *18*(2), 227–245. https://doi.org/10.1177/0013916586182005

Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. *Journal of Environmental Psychology*, *38*, 1–9. https://doi.org/10.1016/j.jenvp.2013.12.005

United Nations Development Programme. (2014). World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352). In *New York, United* (p. 32). https://doi.org/10.4054/DemRes.2005.12.9

Valtchanov, D., Barton, K. R., & Ellard, C. (2010). Restorative effects of virtual nature settings. *Cyberpsychology, Behavior, and Social Networking*, *13*(5), 503–512. https://doi.org/10.1089/cyber.2009.0308

Valtchanov, D., & Ellard, C. G. (2015). Cognitive and affective responses to natural scenes: Effects of low level visual properties on preference, cognitive load and eye-movements. *Journal of Environmental Psychology*, *43*, 184–195. https://doi.org/10.1016/j.jenvp.2015.07.001

van Dooren, M., de Vries, J. J. G. G. J., & Janssen, J. H. (2012). Emotional sweating across the body: Comparing 16 different skin conductance measurement locations. *Physiology and Behavior*, *106*(2), 298–304. https://doi.org/10.1016/j.physbeh.2012.01.020

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Gonzalez-Mora, J. L., Leder, H., Modroño, C., Nadal, M., Rostrup, N., & Skov, M. (2015). Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions. *Journal of Environmental Psychology*, *41*, 10–18. https://doi.org/10.1016/j.jenvp.2014.11.006

Wandersman, A., & Nation, M. (1998). Urban neighborhoods and mental health. *American Psychologist*, *53*(6), 647–656. http://positiveemotions.gr/library_files/W/Wandersman_Nation_Urban_1998.pdf

Weil, A. S., Hernández, G. P., Suslow, T., & Quirin, M. (2019). Implicit affect and autonomous nervous system reactions: A review of research using the implicit positive and negative affect test. *Frontiers in Psychology*, *10*(JULY), 1634. https://doi.org/10.3389/fpsyg.2019.01634

Wilkinson, P. F. (1988). The historical roots of Urban open space planning. *Leisure Studies*, *7*(2), 125–143. https://doi.org/10.1080/02614368800390121

Yin, J., Zhu, S., MacNaughton, P., Allen, J. G., & Spengler, J. D. (2018). Physiological and cognitive performance of exposure to biophilic indoor environment. *Building and Environment*, *132*, 255–262. https://doi.org/10.1016/j.buildenv.2018.01.006

Zadra, J. R., & Clore, G. L. (2011). Emotion and perception: The role of affective information. *Wiley Interdisciplinary Reviews: Cognitive Science*, *2*(6), 676–685. https://doi.org/10.1002/wcs.147

Zarghami, E., Karimimoshaver, M., Ghanbaran, A., & SaadatiVaghar, P. (2019). Assessing the oppressive impact of the form of tall buildings on citizens: Height, width, and height-to-width ratio. *Environmental Impact Assessment Review*, *79*, 106287. https://doi.org/10.1016/j.eiar.2019.106287