

How Architectural Style, Height, and Complexity Influence Perceived Oppressiveness in Urban Spaces

by

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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.

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Abstract

The design of urban environments strongly influences psychological experience, yet research on how building form influences affective responses remains limited. This study used immersive virtual reality to examine the combined effects of architectural style (modern vs. contemporary), building height (low-, mid-, and high-rise), and façade complexity (low, medium, high) on affective perceptions of urban streetscapes. Forty-nine participants explored 18 virtual environments and rated each on oppressiveness, openness, restoration, arousal, and environmental liking. Results showed that greater building height consistently increased perceived oppressiveness and arousal while reducing openness, stress restoration, and liking. Greater façade complexity increased preference, openness, and restoration, and buffered the oppressive effects of high-rises, particularly in modern-style settings. Participants also expressed a clear preference for low- and mid-rise settings over high-rises. These findings reiterate and expand on the restorative and aesthetic benefits of architectural complexity and the value of human-scale design in supporting psychological well-being in urban dwellings.

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Chapter 1: Introduction

Since the Industrial Revolution, urbanization has significantly changed the way humans live. Over 55% of the world's population now resides in cities, and this number is expected to rise to 68% by 2050 (United Nations, 2015). While urban migration has brought many advantages, such as increased commerce, innovation, and cultural exchange, it has also introduced new challenges to people's physical and mental health (Bettencourt & West, 2010). Epidemiological studies indicate that city residents face a higher risk of mental illness compared to those in rural areas. For example, research has linked urban living to a higher prevalence of mood and anxiety disorders, often attributed to increased urban stress (breeder effect) in city environments (Peen et al., 2009; Galea et al., 2005). In Canada alone, four out of five people live in cities, and each year, one in five Canadians experiences a mental health problem (Smetanin et al., 2011). Therefore, understanding how the features of urban built environments influence mental health and well-being is critically important.

Cities increasingly feature high-rise buildings driven by land scarcity, economic factors, and population growth, leading many urban centers to build upward (Ali & Al-Kodmany, 2012). Toronto now ranks third in North America for skyscrapers and aims to surpass Chicago, with 100 high-rises under construction, 300 more proposed, and 220 cranes in use (Ragan, 2023). While these structures serve vital economic and functional roles, their psychological effects are becoming more noticeable. High-rises can act as ambient stressors; perceptible, chronic environmental conditions with a negative emotional tone (Campbell, 1983). Dense clusters of high-rises create a sensory and social environment that subtly affects psychological states. Environmental psychology research, though still somewhat specialized, has examined how high-rises influence oppressiveness, restoration, openness, and arousal. These constructs have been shown to capture both the negative and positive dimensions of urban experience, allowing researchers to examine whether an environment feels constraining, and whether it supports relaxation, feelings of spaciousness, generates stimulation, or is aesthetically

preferred. Including these measures, therefore, provides a more global understanding of how variations in height, façade complexity, and architectural style influence the overall psychological quality of urban settings.

Oppressiveness in environmental psychology refers to a negative feeling of pressure, confinement, or encroachment caused by one's surroundings. Research shows that high-rise urban streetscapes are especially likely to evoke these feelings. Asgarzadeh et al. (2012) found that pedestrians viewing streets with very tall buildings reported significantly higher levels of oppressiveness than those viewing low-rise streets. This has been described as an invasion of personal space, often leading to stress or anxiety. People may feel psychologically smaller or even threatened when walking between tall structures (Joye & Dewitte, 2016). Dense high-rise areas create "urban canyons," which tend to limit sightlines and visible sky, intensifying this sense of enclosure (Wang & Munakata, 2024). Recent research in landscape and urban planning confirms that physical factors such as building height, shape, and façade characteristics are strong predictors of perceived oppressiveness (Zarghami et al., 2019; Wang & Munakata, 2024). Several studies have also found that natural elements can reduce these effects. The presence of trees, vegetation, or open spaces in high-rise environments can soften the visual impact of high-rises, leading to lower ratings of oppressiveness (Lindal & Hartig, 2013; 2015). These findings suggest that the design of high-rise buildings can significantly influence how oppressive they feel, which led to the present study's focus on whether the visual complexity of a façade can affect pedestrians' feelings of oppressiveness.

Restoration explains how environments support recovery from stress or mental exhaustion. According to the Attention Restoration Theory (Kaplan & Kaplan, 1989) and stress recovery (Ulrich et al., 1991), natural settings, with their greenery and openness, promote affective and physiological recovery, while busy or monotonous urban landscapes can hinder it. Restoration is usually measured

by improved well-being, lower stress, or better attention after exposure to a specific environment. There is growing interest in whether tall buildings in densely developed areas limit restoration opportunities compared to shorter, human-scaled streetscapes. Lindal and Hartig (2013) found that taller buildings were linked to lower perceived restoration potential; participants felt less relaxed or "restored" in streets with high-rise buildings than in those with shorter structures. They also observed that taller buildings reduced the feeling of "being away"—the mental escape from daily demands—because dense high-rise environments might serve as constant reminders of urban and social pressures. Importantly, further research by Al-Kodmany (2012) argues that architectural variation positively affects perceived restoration, stating that a greater variety of visually appealing façades can help offset the negative effects of high-rise buildings.

Openness describes the perceived spaciousness or amount of free space within an environment. A highly open space might feature wide streets, abundant visible sky, and long sightlines, whereas an enclosed space offers limited visible expanse and can feel cramped. The sense of openness greatly influences preferences and satisfaction, as people tend to find open, green areas more relaxing and less claustrophobic than densely built environments (Nasar, 1994; Kaplan, 1995). Naturally, tall buildings often reduce perceived openness; Asgarzadeh et al. (2012) found that settings with high-rise structures felt more oppressive and scored lower on openness. When skyscrapers surround pedestrians closely, less of the sky is visible, making the area feel closed in. Urban planners have devised strategies to enhance openness in high-density settings. For instance, New York City's 1916 Zoning Resolution mandated setbacks on tall buildings, improving light, air flow, and creating a more open, pedestrian-friendly environment (New York City Department of City Planning, n.d.). These approaches demonstrate that architectural design can preserve a sense of openness even in crowded urban areas. Relatedly, Mazumder, Spiers, and Ellard (2020) showed that high-rise building

environments were directly linked to heightened stress responses and reduced perceptions of openness in both real-world and virtual reality settings when compared to low-rise buildings.

Arousal is often associated with a state of physiological and psychological activation, ranging from calm (low arousal) to excited or stressed (high arousal). Urban environments, with their noise, crowds, and sensory overload, tend to cause higher arousal than natural surroundings (Evans, 2003; McEwen, 1998). Ulrich et al. (1991) showed this in a well-known study, indicating that viewing unpleasant urban scenes increased physiological stress markers such as heart rate and muscle tension, while viewing nature scenes helped speed recovery and lowered arousal. In a recent virtual reality experiment, participants reported higher arousal levels and displayed stronger stress responses when looking at high-rise buildings compared to low-rise buildings (Mazumder et al., 2020). Understanding how built environments influence arousal is essential for urban planning, as architectural choices that overstimulate may lead to chronic stress, whereas designs that balance stimulation with awe can help create healthier, more engaging cities.

Environmental liking, or aesthetic preference, is another important dimension of how people evaluate built environments. Research in environmental psychology has shown that visual qualities such as ornamentation, variation, and complexity strongly influence whether spaces are perceived as attractive or dull (Srikantharajah & Ellard, 2024; Al-Kodmany, 2012). Façades with greater visual complexity are generally preferred and rated as more beautiful and engaging, while monotonous façades are generally less liked and associated with boredom and displeasure (Srikantharajah & Ellard, 2024). Lindal and Hartig (2013) found that greater architectural variation (i.e. entropy) in residential streetscapes increased both aesthetic preference and perceptions of restorative potential, indicating a close link between complexity and psychological well-being. Another study by Negami and Ellard (2023) found that specific architectural properties such as immensity, sanctity, and

adornment can elicit feelings of awe in participants. These studies point to the importance of beauty and complexity in our built environments, emphasizing the importance of exploring how architectural style and façade complexity influence our preference in built environments.

1.1 Current Study

The literature on oppressiveness, restoration, openness, preference, and arousal highlights how high-density urban forms can influence both psychological states and physiological responses. They shape the pedestrian experience in ways that can reduce perceived openness, increase feelings of oppressiveness and arousal, and limit opportunities for restoration (Asgarzadeh et al., 2012; Lindal & Hartig, 2013; Mazumder et al., 2020). Prior research has examined how features such as building height and window ratios influence these outcomes; however, less is known about the role of façade complexity and architectural style in shaping pedestrian experience. The present study addresses this gap by using immersive virtual reality settings to test how variations in façade complexity and style affect perceptions of oppressiveness, restoration, openness, and arousal.

Virtual reality was chosen for this study because it allows people to experience architectural spaces in a more realistic way than looking at photographs or screen-based images. It gives participants a sense of scale, depth and spatial presence, which is especially important when studying building height and style. Furthermore, VR lets the researcher control every aspect of the environment, something that is not possible in real-world field studies. Along with high experimental control, VR has also been shown to have higher ecological validity when compared to image-based studies (Parsons, 2015). More recently, evidence has shown that photorealistic VR setups can evoke cognitive and emotional responses very similar to real-world experiences (Schöne et al., 2023). For these reasons, VR offers a useful middle ground between realism and experimental control and is well-suited for testing how people emotionally and perceptually respond to different urban settings.

Chapter 2: Materials and Methods

1.2 Participants

A total of 49 undergraduate students (46 females, 3 males; $M = 20.57$ years) were recruited from the University of Waterloo's SONA research pool in March 2025. Participants received 0.75 course credits as compensation for their participation. Ethical approval for this study was obtained from the University of Waterloo's Office of Research Ethics (ORE #46754, approved on 11 February 2025).

1.3 Environments

The urban buildings used in this study were selected from a free-to-use content library in SketchUp. Two architectural styles were chosen and labelled as "modern" and "contemporary" for simplicity. These terms were used as practical descriptors rather than strict architectural categories. The modern style was a plain brick and concrete building, while the contemporary style featured more variation in ornamentation and surface details. The goal was simply to create two distinct groups of buildings that differed in visual character while keeping features such as height and width consistent.

All buildings were modelled to follow the City of Toronto's building height guidelines, which define low-rise buildings as 4 storeys or fewer, mid-rise as 5 to 14 storeys, and high-rise as 14 or more storeys (City of Toronto, 2013, 2018, 2022). Each building was also created at three levels of façade complexity: low, medium, and high. Complexity was defined based on how much detail and visual variation were present in the façade, ranging from flat and minimal to more textured and ornate. To confirm that the complexity levels were objectively valid, JPEG compression was used to measure how much each image file was reduced in size. Since more complex images tend to

compress less, the percent change in file size provided an objective measure of complexity. As expected, these values closely matched the originally assigned complexity levels (see Figure 3).

All models were rendered into realistic urban environments using Lumion, an architectural visualization software, complete with sidewalks, streets, and cars.



Figure 2. Low, mid and high-rise height levels demonstrated using the low-complexity modern architectural style.



Figure 1. The modern (left) and contemporary (right) architectural style, and the three levels of complexity from low, medium and high complexity (left to right)

	Complexity Level	Original Size (KB)	Compressed Size (KB)	% Reduction
	Modern Low-Complexity	470.0	122.7	-74%
	Modern Medium-Complexity	559.1	133.0	-76%
	Modern High-Complexity	319.6	110.7	-65%
	Contemporary Low-Complexity	481.6	139.9	-71%
	Contemporary Medium-Complexity	371.5	115.2	-69%
	Contemporary High-Complexity	480.4	154.7	-68%

Figure 3. JPEG compression results for the three levels of complexity for both architectural styles

1.4 Procedure

Participants used an HTC VIVE virtual reality headset to experience a series of 18 virtual urban environments. These environments differed in two architectural styles (modern and contemporary), three levels of architectural complexity (low, medium, high), and three building heights (4, 11, and 40 stories), creating a $2 \times 3 \times 3$ within-subjects design. The order of environments was randomized for each participant to prevent order effects.

1.4.1 Preliminary Questions

At the start of the session, before putting on the VR headset, participants completed a short questionnaire about their childhood environment (rural, town, suburb, or city) and were informed of potential side effects of prolonged VR use. This questionnaire was conducted to test if there are any affective differences in how people of different backgrounds perceive the buildings in this study.

The participants were then shown image samples of six mid-rise models at each level of complexity (low, medium, high) for both architectural styles, allowing them to become familiar with the types of models they would later encounter in VR. Participants rated each model on three 7-point Likert scales, assessing perceived complexity (1 = Simple, 7 = Complex), interestingness (1 = Boring, 7 = Interesting), and beauty (1 = Ugly, 7 = Beautiful)

1.4.2 Main Study

During the main phase of the study, participants were fitted with the VR headset and seated in a rotating chair and asked to visually explore each environment in a 360-degree panorama (Figure 4). After approximately one minute of viewing each setting, they rated how much they liked the setting, as well as how oppressive, restorative, open, and arousing the space felt, using a 7-point Likert scale. The oppressiveness item asked, "To what extent does this setting make you feel confined or constrained?" (1 = Not confined at all, 7 = Extremely confining). Restoration was measured by

asking, "To what extent does this setting make you feel relaxed or restored?" (1 = Not relaxing at all, 7 = Extremely relaxing). Environmental liking was measured with "How much do you like this setting?" (1 = I do not like it at all, 7 = I like it a lot). For openness, participants were asked, "How open did you perceive the setting to be?" (1 = Not open at all, 7 = Extremely open). And arousal was measured by asking, "How arousing or stimulating do you find this setting?" (1 = Extremely boring, 7 = Extremely arousing). Ratings were recorded by the researcher while participants remained immersed in the VR environment.

The entire procedure took about 45 minutes. Participants were debriefed at the end of the session and earned course credits for their participation. The HTC VIVE headset was disinfected with alcohol wipes after each use to ensure proper sanitation.



Figure 4. Examples of the 360-degree panoramas seen by participants

Chapter 3: Results

1.5 Preliminary ratings

A repeated measures ANOVA was conducted to see if the different levels of façade complexity significantly differed from one another based on participants' initial ratings of beauty, complexity and interestingness. Mauchly's test indicated that the assumption of sphericity was violated for the following effects and interactions; therefore, Greenhouse–Geisser corrections were applied.

1.5.1 Beauty Rating

For the beauty measure, there was a significant style and complexity interaction, $F(1.54, 73.79) = 6.17, p < .007, \eta^2 = .114$. As shown in Figure 5, participants rated the building models as increasingly beautiful with higher levels of complexity in both architectural styles. For the modern style, a significant main effect of complexity emerged, $F(1.63, 78.08) = 44.67, p < .001, \eta^2 = .482$. Mean beauty ratings increased from low- ($M = 2.22$) to medium- ($M = 3.64$) and high-complexity ($M = 4.12$). Bonferroni post hoc tests revealed that the differences between low and medium, as well as between low and high complexity, were statistically significant ($p < .001$), whereas the difference between medium and high complexity was not significant ($p = .061$).

For the contemporary style, there was also a significant main effect of complexity on beauty, $F(1.42, 68.36) = 131.75, p < .001, \eta^2 = .733$. Beauty ratings increased from low ($M = 3.57$) to medium ($M = 4.63$) and high complexity ($M = 5.94$), with all pairwise differences reaching statistical significance (all $p < .001$).

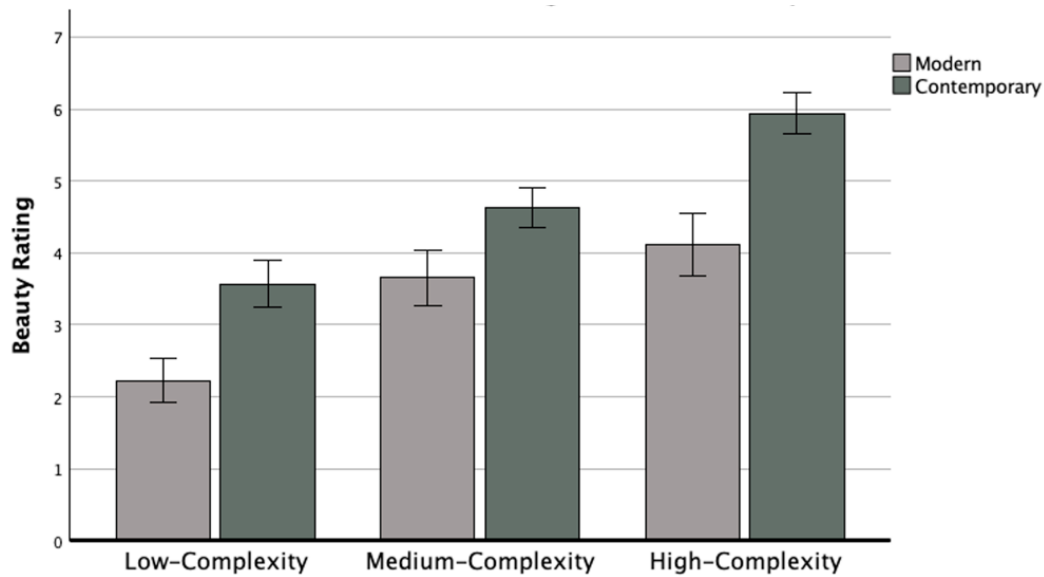


Figure 5. Bar graph showing mean participant ugly to beautiful rating for complexity levels of the modern and the contemporary style. Error bars represent 95CI.

1.5.2 Complexity Rating

Since the buildings' façade complexity levels were defined a priori, we also wanted to verify whether these categories aligned with participants' perceptions of complexity alongside the JPEG compression results. A repeated-measures ANOVA revealed a significant style and complexity interaction, $F(1.61, 77.46) = 4.82$, $p = .016$, $\eta^2 = .091$.

For the modern style, main effects analyses showed a significant effect of the predefined complexity categories on participants' complexity ratings, $F(1.60, 76.72) = 271.67$, $p < .001$, $\eta^2 = .850$. As shown in Figure 6, mean complexity ratings increased from low ($M = 1.47$) to medium ($M = 3.37$) to high ($M = 4.98$), with all pairwise differences statistically significant ($p < .001$).

A similar pattern was found for the contemporary style, $F(1.67, 79.94) = 277.89$, $p < .001$, $\eta p^2 = .853$, where ratings increased from low ($M = 3.00$) to medium ($M = 4.43$) to high ($M = 6.08$). Bonferroni-adjusted comparisons again confirmed significant differences between all three levels (all $p < .001$).

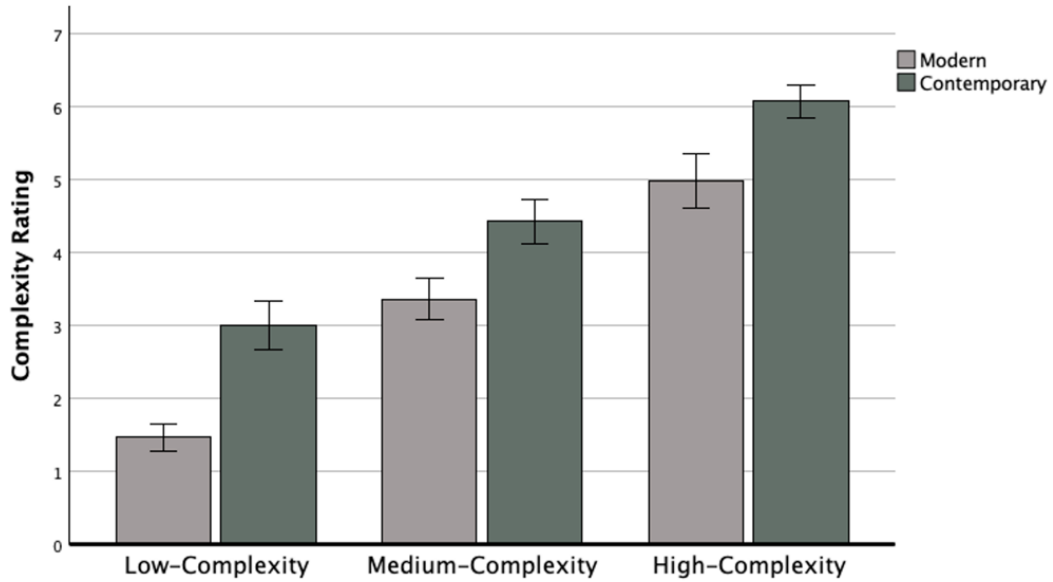


Figure 6. Bar graph showing mean participant simple to complex rating for levels of modern and contemporary architectural styles, Error bars represent 95CI.

1.5.3 Interestingness Rating

Participants also rated each model on a boring-to-interesting scale. There was a marginally non-significant interaction between complexity and style, $F(2, 96) = 2.98$, $p = .055$. As shown in Figure 7, interest ratings increased with greater façade complexity for both architectural styles. For the modern style, $F(1.77, 84.79) = 119.18$, $p < .001$, $\eta p^2 = .713$, mean ratings rose from low ($M = 1.35$) to medium ($M = 3.16$) to high complexity ($M = 4.33$), with all pairwise differences statistically significant ($p < .001$).

For the contemporary style, $F(1.60, 76.72) = 271.67$, $p < .001$, $\eta^2 = .850$, ratings similarly increased from low ($M = 2.67$) to medium ($M = 3.96$) to high complexity ($M = 5.61$). Bonferroni-adjusted comparisons again showed significant differences between all three levels ($p < .001$).

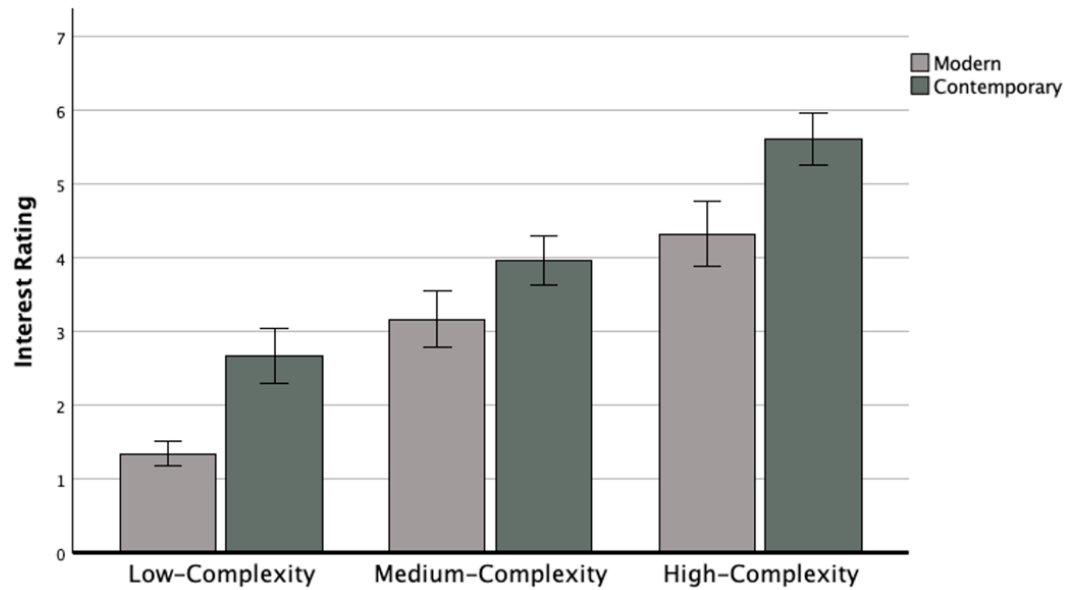


Figure 7. Bar graph showing mean participant boring to interesting rating for the complexity levels of the modern and the contemporary style. Error bars represent 95CI.

1.6 Main Experiment

1.6.1 Oppressiveness

A repeated-measures ANOVA was conducted to examine the effects of building height, complexity, and style on participants' ratings of oppressiveness. Mauchly's test indicated that the assumption of sphericity was violated for the height and complexity factors, so Greenhouse–Geisser corrections were applied.

There was a significant main effect of height, $F(1.53, 73.31) = 108.34, p < .001, \eta^2 = .693$. Participants perceived oppressiveness to increase steadily from low-rise buildings ($M = 2.44$) to mid-rises ($M = 3.41$) and high-rises ($M = 4.44$).

There was no significant three-way interaction between height, complexity and style on oppressiveness, $F(2.86, 137.47) = 0.78, p = .537$. The only significant interaction was between style and complexity, $F(2, 96) = 8.31, p < .001, \eta^2 = .148$. Simple effects tests with Bonferroni correction were used to examine this interaction. For the modern style, there was a significant main effect of complexity on oppressiveness, $F(1.61, 77.21) = 26.13, p < .001, \eta^2 = .353$. Pairwise comparisons indicated that low-complexity buildings were rated as more oppressive than both medium- ($p < .001$) and high-complexity buildings ($p < .001$), and medium complexity was rated as more oppressive than high complexity ($p = .038$).

For the contemporary style, there was also an effect of complexity, $F(1.59, 76.23) = 3.38, p = .050, \eta^2 = .066$. However, the only significant pairwise difference was between low- and high-complexity buildings ($p = .014$). No differences were observed between low and medium ($p = .489$) or between medium and high complexity ($p = .999$).

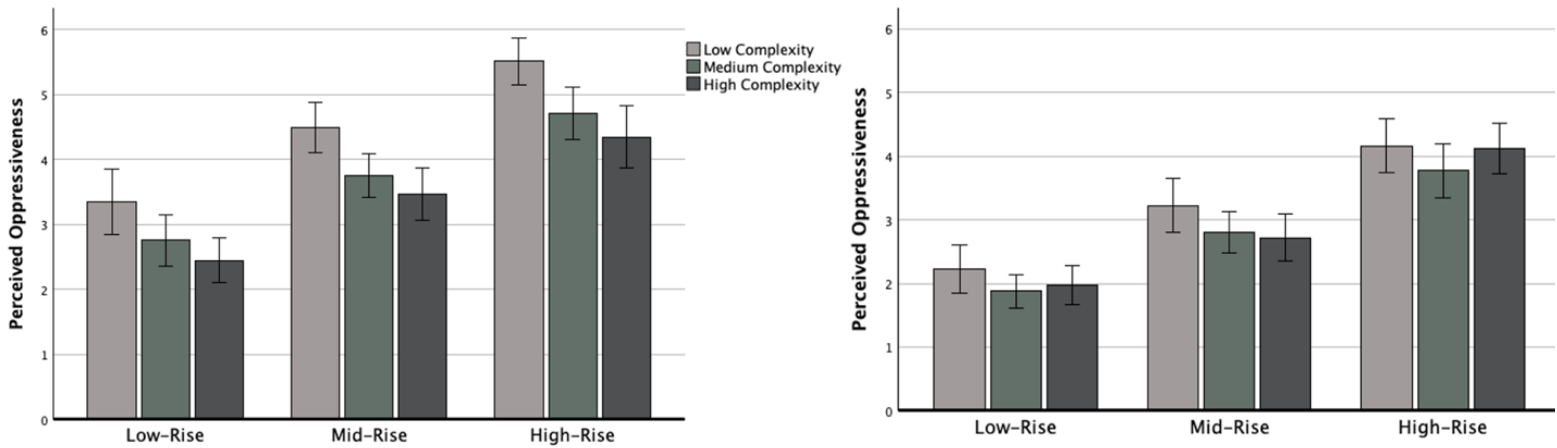


Figure 8. shows perceived oppressiveness rating for the modern style (left) and the contemporary style (right). Error bars represent 95CI.

1.6.2 Restoration

A repeated-measures ANOVA was conducted to examine the effects of building height, complexity, and style on participants' ratings of restoration. There was no significant three-way interaction between height, complexity and style on restorative potential, $F(3.33, 159.82) = 1.97, p = .114$. The analysis revealed only a significant height and style interaction, $F(2, 96) = 3.67, p = .029, \eta^2 = .071$.

For the modern style, the assumption of sphericity was violated, so Greenhouse–Geisser corrections were applied. Restorative potential decreased as building height increased, $F(1.52, 73.08) = 12.97, p < .001, \eta^2 = .213$. Bonferroni-adjusted comparisons indicated that low-rises were rated as more restorative than high-rises ($p < .001$), and mid-rises were also rated as more restorative than high-rises ($p < .001$). The difference between low- and mid-rises was not significant ($p = .152$).

For the contemporary style, the assumption of sphericity was again violated, and Greenhouse–Geisser corrections were applied. There was a significant main effect of height, $F(1.67, 80.12) = 55.14, p < .001, \eta^2 = .535$. Restoration ratings decreased consistently with increasing height, with Bonferroni-adjusted comparisons showing significant differences between all three height levels (all $p < .005$).

There was also a significant complexity x style interaction, $F(2, 96) = 6.55, p = .002, \eta^2 = .120$. For the modern style, Greenhouse–Geisser corrections were applied, and complexity had a significant effect on perceived restoration, $F(1.71, 81.90) = 26.03, p < .001, \eta^2 = .352$. Pairwise comparisons showed that both medium- and high-complexity façades were rated as more restorative than low-complexity façades ($p < .001$). The difference between medium and high complexity was not significant ($p = .189$).

For the contemporary style, the effect of complexity did not reach significance, $F(1.58, 75.88) = 3.18, p = .059, \eta^2 = .062$.

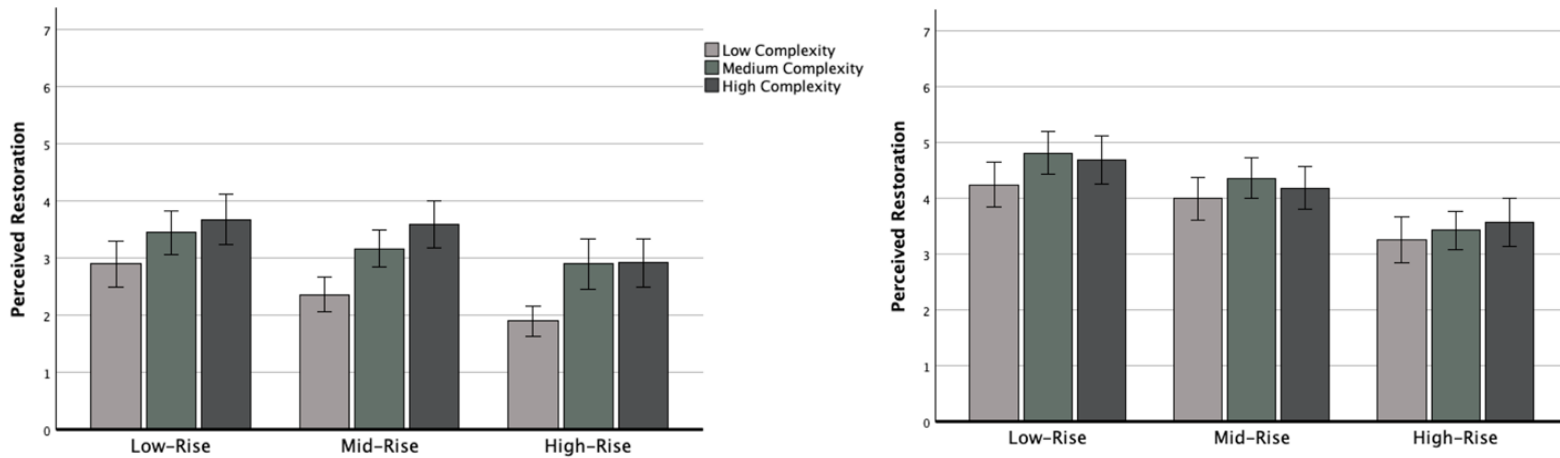


Figure 9. shows perceived restoration for the modern architectural style (left) and the contemporary style (right). Error bars represent 95CI.

1.6.3 Environmental Liking

A repeated-measures ANOVA was conducted to examine the effects of building height, complexity, and style on participants' preference ratings of each setting. A repeated-measures ANOVA with Greenhouse–Geisser correction revealed a significant main effect of complexity, $F(1.60, 76.88) = 51.38, p < .001, \eta^2 = .517$. Bonferroni-adjusted comparisons showed that participants generally preferred more complex façades over simpler ones, with all three levels of complexity differing significantly from one another (all $p < .046$). Mean ratings were lowest for low-complexity façades ($M = 2.95$), followed by medium ($M = 3.83$) and high-complexity façades ($M = 4.09$).

There was no significant three-way interaction between height, complexity and style on participant preference, $F(4, 102) = 0.69, p = .581$. There was a significant height x style interaction, $F(2, 96) = 10.49, p < .001, \eta^2 = .179$. For the modern style, a Greenhouse–Geisser corrected ANOVA revealed a significant main effect of height, $F(1.47, 70.46) = 7.22, p = .004, \eta^2 = .131$.

However, Bonferroni comparisons indicated that this effect was driven only by the difference between low- and high-rise buildings ($p = .012$), as there were no significant differences between low- and mid-rises ($p = .060$) or between mid- and high-rises ($p = .110$).

For the contemporary style, a Greenhouse–Geisser corrected ANOVA also revealed a significant main effect of height, $F(1.67, 80.12) = 55.14$, $p < .001$, $\eta^2 = .535$. Unlike the modern style, Bonferroni comparisons showed significant differences between high-rise buildings and both low- and mid-rise buildings ($p < .001$). However, no difference was observed between low- and mid-rises ($p = .999$).

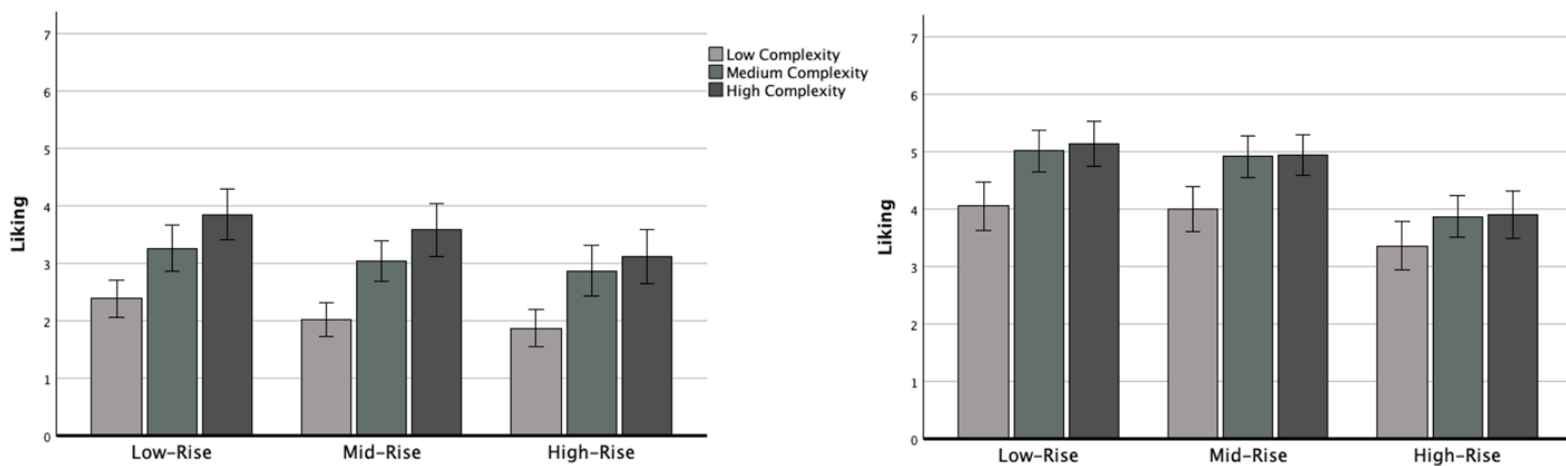


Figure 10. shows participants preference rating for the modern architectural style (left) and the contemporary style (right). Error bars represent 95CI.

1.6.4 Openness

A repeated-measures ANOVA was conducted to examine the effects of building height, complexity, and style on participants' ratings of openness. The analysis, with Greenhouse–Geisser correction applied, revealed a significant main effect of height on perceived openness, $F(1.61, 77.21)$

= 112.94, $p < .001$, $\eta^2 = .702$. Openness decreased from low-rise buildings ($M = 4.81$) to mid-rises ($M = 3.93$) and high-rises ($M = 3.05$). Bonferroni-adjusted comparisons confirmed that all three height levels significantly differed from one another (all $p < .001$).

There was no significant three-way interaction between height, complexity and style on perceived openness, $F(4, 192) = 1.51$, $p = .200$. The only significant interaction for openness was a complexity x style interaction, $F(2, 96) = 20.61$, $p < .001$, $\eta^2 = .300$. For the modern style, a Greenhouse–Geisser corrected ANOVA revealed a significant main effect of complexity, $F(1.50, 72.04) = 30.48$, $p < .001$, $\eta^2 = .388$. Participants rated high-complexity façades ($M = 4.00$) as more open than medium-complexity façades ($M = 3.59$) and low-complexity façades ($M = 2.78$). Bonferroni comparisons showed that all three levels of complexity significantly differed from one another (all $p < .005$).

For the contemporary style, there was no significant main effect of complexity on perceived openness, $F(1.86, 89.39) = 1.31$, $p = .274$, $\eta^2 = .027$.

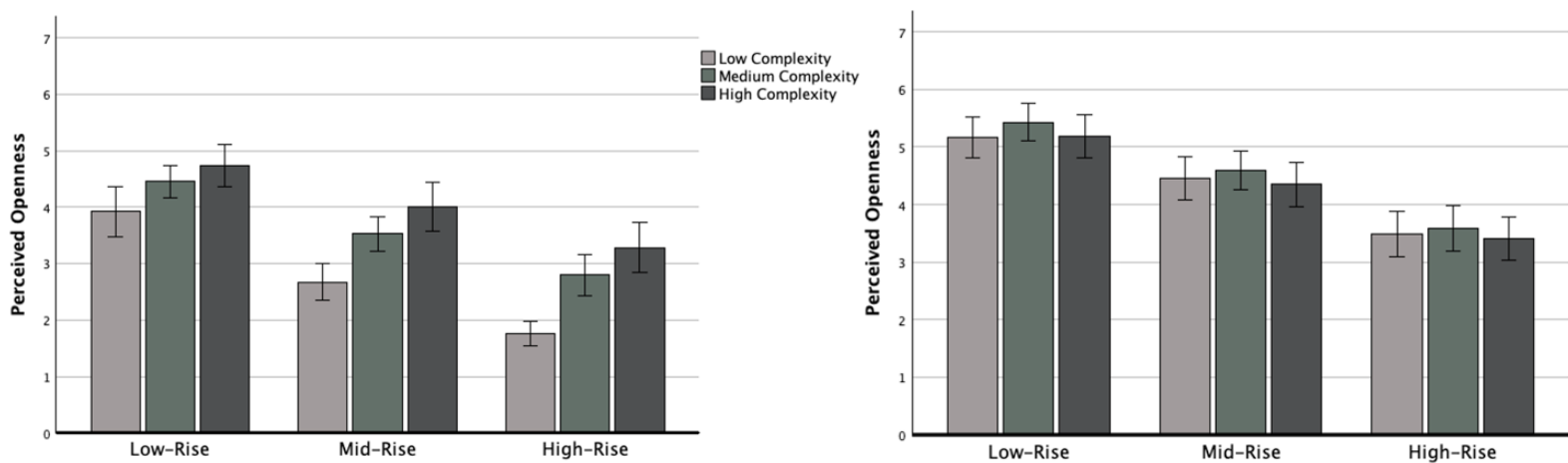


Figure 3. shows perceived openness for the modern architectural style (left) and the contemporary style (right). Error bars represent 95CI

1.6.5 Arousal

A repeated-measures ANOVA was conducted to examine the effects of building height, complexity, and style on participants' ratings of arousal. There was no significant three-way interaction between height, complexity and style on arousal, $F(3.39, 162.76) = 1.00$, $p = .399$. However, the analysis revealed a significant height and complexity interaction, $F(4, 192) = 2.54$, $p = .041$, $\eta^2 = .050$. All subsequent effects violated Mauchly's test of sphericity, so Greenhouse–Geisser corrections were applied.

There was a significant simple effect of complexity within the low-rise condition, $F(1.67, 80.35) = 17.83$, $p < .001$, $\eta^2 = .271$. Participants generally found more complex buildings to be more arousing, with low-complexity façades ($M = 2.79$) rated as less arousing than medium- ($M = 3.22$) and high-complexity façades ($M = 3.84$). Bonferroni-adjusted comparisons indicated that low- and medium-complexity buildings did not significantly differ ($p = .092$), whereas low- and high-complexity buildings ($p < .001$) and medium- and high-complexity buildings ($p < .001$) differed significantly.

There was also a significant simple effect of complexity within the mid-rise condition, $F(1.58, 75.74) = 16.30$, $p < .001$, $\eta^2 = .254$. Similar to the low-rise condition, participants found more complex façades to be more arousing, with low-complexity façades ($M = 3.00$) rated lower than medium- ($M = 3.41$) and high-complexity façades ($M = 4.01$). A Bonferroni test showed that all levels differed significantly ($p < .001$), except between low- and medium-complexity façades ($p = .141$).

Finally, there was a significant simple effect of complexity within the high-rise condition, $F(1.66, 135.00) = 5.92$, $p = .006$, $\eta^2 = .110$. Participants again found more complex façades to be more arousing, although this was only significant between low- ($M = 3.54$) and high-complexity façades ($M = 4.12$), $p = .019$. No other difference reached significance.

There was a significant height and style interaction for arousal, $F(2, 96) = 4.22$, $p = .018$, $\eta^2 = .081$. For the modern style, there was a significant simple effect of height on arousal, $F(1.58, 75.67) = 17.30$, $p < .001$, $\eta^2 = .265$. Participants tended to find taller buildings more arousing, with low-rise buildings ($M = 2.84$) rated as less arousing than mid-rise ($M = 3.06$) and high-rise buildings ($M = 3.61$). Bonferroni-adjusted comparisons showed significant differences between all height levels (all $ps < .001$) except between low- and mid-rise buildings ($p = .088$).

No significant main effect of height on arousal was found for the contemporary style, $F(1.72, 82.52) = 2.86$, $p = .071$, $\eta^2 = .056$.

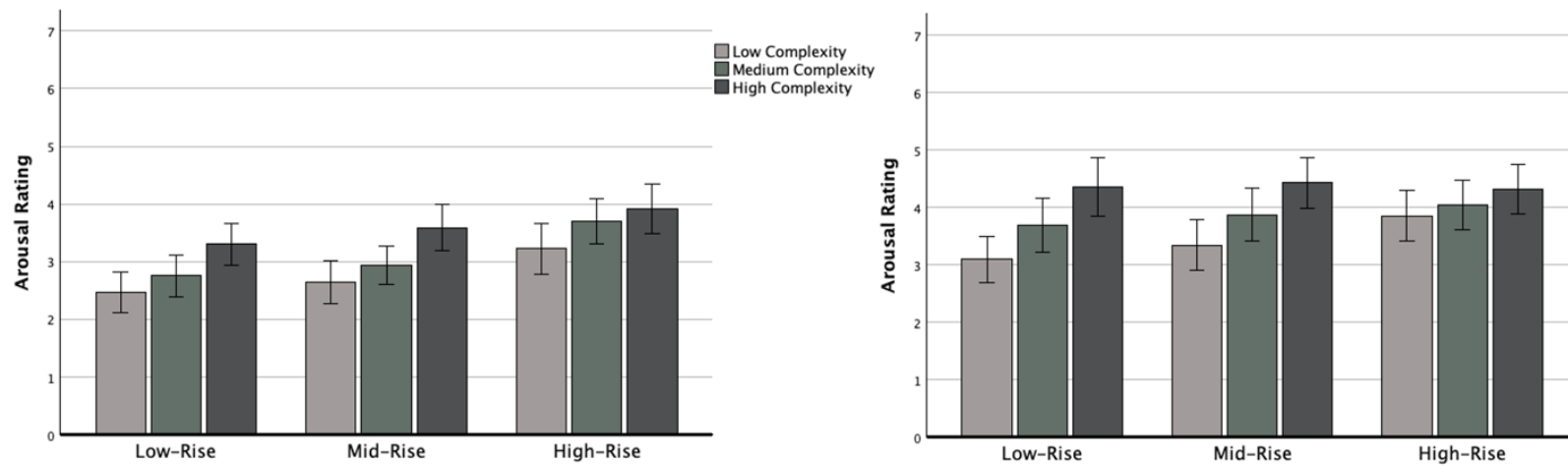


Figure 4. shows arousal rating for the modern architectural style (left) and the contemporary style (right). Error bars represent 95CI.

1.7 Individual Differences

To determine whether participants' reported upbringing environment (rural, town, suburban, or urban) influenced their ratings of oppressiveness, restoration likelihood, openness, liking, and arousal across different building heights, complexity levels, or architectural styles, we re-ran the repeated measures ANOVA with upbringing included as a between-subjects factor. No significant main effects or interactions were found for upbringing environment on any of the measured variables.

Chapter 4: Discussion

The purpose of this study was to explore how building height, façade complexity, and architectural style influence people's emotional and perceptual experiences of urban environments. The main question was whether increasing façade complexity could soften the negative effects of verticality, such as feelings of confinement or *negative arousal*, while supporting more positive qualities like restoration, openness, and liking. The following sections discuss how each of these outcomes was shaped by the architectural features of the environments and what these results suggest for the design of more psychologically supportive urban spaces.

1.8 Oppressiveness

The present study showed that building height was a consistent driver of perceived oppressiveness, with taller buildings producing stronger feelings of confinement and reduced openness. This finding corresponds with earlier work showing that high-rise structures often elicit negative emotional reactions in dense urban contexts (Mazumder et al., 2020; Lindal & Hartig, 2013). The interaction between façade complexity and style also played a role in shaping the experience of oppressiveness. For both styles, participants generally found more complex façades to be less oppressive than simple, low-complexity façades. Although little research has been done on the effects of façade complexity on oppressiveness, the results from this study parallels related research showing that architectural variation and ornamentation contribute to more positive affective responses and reduce the monotony that can amplify feelings of discomfort in urban spaces (Lindal & Hartig, 2013; Negami & Ellard, 2023; Srikantharajah & Ellard, 2024).

1.9 Openness

Openness is often conceptualized as the inverse of oppressiveness, with one reflecting perceived expanse and the other perceived enclosure (Asgarzadeh et al., 2012). Consistent with this interpretation, ratings of openness followed an opposite pattern to those of oppressiveness. Height strongly reduced perceived openness across both architectural styles, reinforcing Mazumder, Spiers, and Ellard's (2020) findings that high-rises diminish perceived spatial openness when compared to low-rises. In the modern style, greater façade complexity consistently enhanced openness. Complexity did not significantly influence openness in the contemporary style. Although more research is necessary, these results indicate that while height is the dominant factor influencing perceived openness, façade complexity can counteract the enclosing effects of verticality; however, it is likely dependent on the stylistic context.

1.10 Aesthetic Preference

Participants' preference for a setting was shaped by both façade complexity and building height. Consistent with the preliminary ratings, more complex façades were generally preferred over simpler ones, supporting recent studies showing that low-complexity buildings tend to be experienced as boring, unattractive, and unpleasant (Srikantharajah & Ellard, 2024). Height also influenced participants' preferences across both styles, with low- and mid-rises generally preferred over high-rises. These findings align with earlier research showing that taller buildings can erode the participants' impression of urban environments (Lindal & Hartig, 2013). Together, the results suggest that participants prefer more complex façades, and that even though high-rises were disliked compared to low- and mid-rises, increased complexity helped alleviate some of the negative impressions of tall buildings.

1.11 Restorativeness

Perceived restorativeness was mostly influenced by height. In both styles, low- and mid-rises were seen as more restorative than high-rises, reintegrating earlier findings that taller structures reduce restorative potential (Lindal & Hartig, 2013). Complexity also impacted restoration potential, but only in the modern condition, where greater complexity increased restoration likelihood. These results suggest that façade complexity may contribute to perceptions of restorative potential, but only within certain stylistic and architectural contexts. The overlap between complexity and restoration observed here is again consistent with Lindal & Hartig's (2013) research, which found a positive effect of a façades entropy on participants' perceived restoration potential.

1.12 Arousal

Arousal ratings revealed a more complex pattern of interactions. In the modern style, height increased arousal, with high-rises rated as more stimulating than low- and mid-rises. Complexity also raised arousal in modern environments, particularly at low and mid heights, suggesting that visual detail fosters attentional engagement. In the contemporary style, arousal was generally higher for more complex façades, with only a weak effect of height. These findings highlight the interplay of complexity and height on arousal. Height-driven arousal may reflect stress or overload, consistent with Mazumder, Spiers, and Ellard (2020), who reported elevated physiological stress in VR environments surrounded by high-rises. Complexity-driven arousal is more likely to reflect fascination or interest. Demonstrated by Srikantharajah and Ellard (2024), who showed that low-complexity buildings were associated with decreases in physiological arousal, interpreted as signs of boredom or perceptual disengagement. Therefore, complexity appears to maintain alertness through interest rather than stress, while building height appears to contribute to arousal that may be more related to stress and oppressiveness.

1.13 Limitations

A potential limitation of this study is that, although the virtual reality setting provided a significant level of experimental control and has been shown to have higher ecological validity than image-based studies, it still does not fully replicate the multisensory experience of being in a real urban environment. Elements such as ambient sound, weather conditions, and social context were necessarily absent, which could limit ecological validity. The degree to which a participant felt to be "present" in the VR setting may have impacted their responses to the measures. Specifically, being in VR may subdue affective responses that would otherwise be strong in real-life studies.

Additionally, the participant sample primarily consisted of Canadian female psychology undergraduates, restricting the generalizability of the results to other age groups, socio-demographic backgrounds, educational levels, and countries. Including more male participants may prove informative, as in earlier VR architectural environment experiments, female participants reported higher arousal, lower potency (i.e., less comfort) and stronger avoidance motivation than male participants, while males showed higher comfort and more positive emotional responses. (Li et al., 2024). Additionally, in a VR stress-induction study, females displayed greater physiological stress responses (e.g., higher heart rate) than males under the same conditions. (Santl et al., 2019). Future research, including these aspects, may reveal specific demographic differences not observed here. Although initial analyses suggested that whether someone grew up in an urban, suburban, rural, or town environment did not influence results, it is difficult to precisely determine how these categories were defined for a given individual; Perceptions of what constitutes a city or suburb can vary.

Another limitation is that the manipulation of architectural complexity was not consistent across the two styles: in the modern style, complexity was increased through more windows and colour, whereas in the contemporary style, it involved added ornamentation and balconies. This could

introduce a confound between stylistic cues and complexity. Future studies should aim for more controlled stimuli where style and complexity are manipulated separately. Lastly, although this study relied on self-reported emotional responses, incorporating physiological measures such as skin conductance or heart rate could improve future research by providing more objective data on arousal and engagement in built environments. As seen in prior research by Mazumder, Spiers, and Ellard (2020), taller buildings have been shown to increase physiological responses such as heart rate and skin conductance, while work by Srikantharajah and Ellard (2024) found that low-complexity façades reduce physiological activation, consistent with perceptual disengagement. Based on these findings and the current results, we would expect that future studies using physiological measures would show stronger stress-related responses in tall, low-complexity environments and lower stress with greater façade complexity. We also predict that high-complexity façades, particularly in low- and mid-rise settings, would produce moderate physiological arousal linked to visual interest rather than stress. Examining these effects together would help clarify how height and complexity interact to influence both the emotional and physiological experience of urban spaces.

1.14 Design Implications

This study's findings have several implications for architectural and urban design. First, strategies to reduce the psychological effects of building height should be prioritized in dense developments. These include increasing the sky-view factor and lowering height-to-width ratios on narrow streets (Zarghami et al., 2019; Wang & Munakata, 2024; Lindal & Hartig, 2013). Second, architectural complexity can be considered when designing buildings to improve the openness and promote restoration, interest, and aesthetic appeal. This supports the idea that boring and ugly building façades, which are linked to decreased engagement and increased boredom (Srikantharajah & Ellard, 2024), should be avoided in favour of designs that encourage interest and visual

exploration. Lastly, although not tested in the current study, incorporating nature and green elements remains an important complement to architectural design strategies. Research indicates that even modest vegetation can lessen perceived oppressiveness and enhance affective responses in urban environments (Lindal & Hartig, 2013).

1.15 Conclusion

This study offers empirical evidence on the psychological effects of architectural design, showing that variations in building height, façade complexity, and architectural style significantly shape how people experience urban environments. Consistent with previous research, we found that higher architectural complexity increases perceived restoration, openness, liking, and arousal, especially in low- and mid-rise settings. Conversely, taller buildings are consistently linked to feelings of oppressiveness and reduced restoration potential.

Our findings emphasize that human-centred urban design requires more than just functionality and density. The importance of aesthetics and the psychological well-being of those who inhabit and navigate the built environment are vital for a rapidly urbanizing society. Incorporating ornamentation, utilizing diverse materials, preserving sky views, and respecting the human scale can greatly improve pedestrian experiences in crowded cities. The connection between architectural features and psychological states highlights the need to move beyond outdated design philosophies that prioritize convenience and cost-efficiency at the expense of residents' lived experiences.

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Appendix A: ANOVA table for oppressiveness

	df	F	p	Partial η^2
Height	1.53, 73.31	108.34	< .001	.693
Complexity	1.38, 66.19	18.08	< .001	.274
Style	1, 48	79.00	< .001	.622
Height $\times$ Complexity	4, 192	0.44	.778	.009
Height $\times$ Style	2, 96	0.60	.552	.012
Complexity $\times$ Style	2, 96	8.31	< .001	.148
Height $\times$ Complexity $\times$ Style	2.86, 137.47	0.78	.537	.016

Style	Comparison	Mean Difference	SE	p (Bonferroni)	95% CI Lower	95% CI Upper
Modern	Low vs Medium	0.707	0.129	< .001	0.387	1.028
Modern	Low vs High	1.027	0.178	< .001	0.587	1.468
Modern	Medium vs High	0.320	0.123	.038	0.014	0.626
Contemporary	Low vs Medium	0.388	0.131	.014	0.063	0.712
Contemporary	Low vs High	0.265	0.187	.489	-0.199	0.730
Contemporary	Medium vs High	-0.122	0.133	1.000	-0.452	0.207

Appendix B: ANOVA table for restoration likelihood

	df	F	p	Partial η^2
Height	1.40, 67.12	39.23	< .001	.450
Complexity	1.45, 69.59	18.69	< .001	.280
Style	1, 48	87.31	< .001	.645
Height $\times$ Complexity	4, 192	0.07	.992	.001
Height $\times$ Style	2, 96	3.67	.029	.071
Complexity $\times$ Style	2, 96	6.55	.002	.120
Height $\times$ Complexity $\times$ Style	3.33, 159.82	1.97	.114	.039

Appendix C: ANOVA table for environmental liking

	df	F	p	Partial η^2
Height	1.41, 67.79	23.60	< .001	.330
Complexity	1.60, 76.88	51.38	< .001	.517
Style	1, 48	149.12	< .001	.756
Height $\times$ Complexity	4, 192	1.38	.242	.028
Height $\times$ Style	2, 96	10.49	< .001	.179
Complexity $\times$ Style	1.76, 84.53	3.09	.057	.061
Height $\times$ Complexity $\times$ Style	4, 192	0.69	.581	.014

Appendix D: ANOVA table for openness

	df	F	p	Partial η^2
Height	1.61, 77.21	112.94	< .001	.702
Complexity	1.55, 74.20	14.89	< .001	.237
Style	1, 48	71.93	< .001	.600
Height $\times$ Complexity	4, 192	0.67	.612	.014
Height $\times$ Style	1.48, 70.95	0.74	.785	.016
Complexity $\times$ Style	2, 85.96	20.61	< .001	.300
Height $\times$ Complexity $\times$ Style	4, 192	1.51	.200	.031

Style	Comparison	Mean Difference	SE	p (Bonferroni)	95% CI Lower	95% CI Upper
Modern	Low vs Medium	-0.810	0.146	< .001	-1.171	-0.448
Modern	Low vs High	-1.224	0.199	< .001	-1.719	-0.730
Modern	Medium vs High	-0.415	0.124	.005	-0.722	-0.108
Contemporary	Low vs Medium	-0.170	0.144	.726	-0.526	0.186
Contemporary	Low vs High	0.054	0.161	1.000	-0.345	0.454
Contemporary	Medium vs High	0.224	0.127	.250	-0.090	0.539

Appendix E: ANOVA table for arousal

	df	F	p	Partial η^2
Height	1.49, 71.49	11.62	< .001	.195
Complexity	1.45, 78.79	18.80	< .001	.281
Style	1, 48	26.03	< .001	.352
Height $\times$ Complexity	4, 192	2.54	.041	.050
Height $\times$ Style	2, 96	4.22	.018	.081
Complexity $\times$ Style	1.76, 84.45	.19	< .801	.004
Height $\times$ Complexity $\times$ Style	3.39, 162.76	1.00	.399	.021