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Emotional Impact of Façade Colors and Materials: A Virtual Reality Study in Rural Switzerland

GEO 511 Master's Thesis

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Abstract

Emotions shape how people perceive and evaluate built environments. In rural Switzerland, exterior façade design is often regulated through restrictions on colors and materials to preserve visual harmony. This thesis tested whether such assumptions are empirically supported by examining the emotional effects of façade color, material and participants' residential background.

A Virtual Reality experiment in Unreal Engine exposed participant to 12 façade scenarios varying in Color (Red, Blue, White). Material (Wood, Concrete) and Location (Street, Backyard). Residential background (City, Agglomeration, Countryside) served as a between–subjects factor. Emotional responses were measured using electrodermal activity (EDA) the Self–Assessment Manikin (SAM) and a questionnaire.

Results showed that Red and Blue increased physiological arousal compared to White but subjective rating remained calming to neutral, without the predicted warm–cool distinction. Material effects emerged mainly for Red. Residential Background influenced physiological arousal, with urban–raised participants responding more strongly, but not subjective preferences.

The findings suggest that exterior façade aesthetics depend less on rigid color or material theories than on contextual familiarity and harmonious integration, supporting more flexible planning regulations. Future research could extend these results by including further hues and color dimensions, materials and more diverse demographic samples.

Keywords: *façade aesthetics, color, material, residential background, rural planning, Switzerland, Virtual Reality, emotional responses, electrodermal activity*

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1. Introduction

Emotions have a spatial character and significantly influence how people perceive, interpret, and interact with their environment. In disciplines such as urban planning, geography, and architecture, understanding the emotional responses to design choices leads to better planning and design solutions. Numerous studies have examined the emotional impact of aesthetics in urban landscapes, public spaces, and building façades, providing insights for future planning projects (Nasar, 1994; Prieto & Oldenhave, 2021; Sussman & Hollander, 2021).

Within the aesthetic spectrum, exterior façade colors and building materials are among the most visually immediate and publicly debated design parameters. The ability of color in architecture to evoke strong emotions has been recognized for decades if not centuries, while material, originally considered primarily in terms of structural function, has gained a broader meaning as a determinant of design aesthetics (Manav, 2017). The effects have been explored in environmental psychology and architectural theory, ranging from classical concepts such as *Le Corbusier's Polychromie Architecturale* (De Heer, 2009; Serra et al., 2016) to more contemporary notions like *Immateriality* (Löschke, 2016).

In Switzerland, building aesthetics are often shaped by regulations which limit design options (Bundesamt für Kultur (BAK), 2020; Departement Bau, Verkehr und Umwelt, Kanton Aargau, 2018; Kanton Glarus, 2022). This leads to discussions and differing opinions among inhabitants and experts like planners, architects and decision makers from municipalities, cantons and the federal state. The regulations aim to protect historical landscape characteristics and ensure visual coherence, but in the meantime they also restrict design freedom. Given their influence on Swiss building environments, it is crucial that regulations are grounded in empirical evidence about aesthetic perception.

1.1 Problem Statement

While research on building aesthetics has predominantly focused on urban areas, rural regions which are characterized by distinct cultural traditions, historical building styles and close integration within the natural landscape are often overlooked. The rural building environments in Switzerland differ substantially from their urban counterparts. Thus, design preferences of colors and materials may not be transferable between these conditions. Even though the current aim in spatial planning of densification also applies to rural regions, these areas often feature building types that are uncommon in urban settings in Switzerland (Der Bundesrat, 2024). This includes for instance higher prevalence of single-family houses, gabled roofs, or combined residential-agricultural structures like farmhouses with integrated barns (Bundesamt für Kultur (BAK), 2020; Bundesgesetz Vom 22. Juni 1979 Über Die Raumplanung, 2019). In Switzerland, approximately 25% of the population resides in rural areas highlighting the importance of understanding their specific aesthetic preferences (Bundesamt für Statistik (BFS), 2024).

Moreover, most studies on architectural color and material design focus on interior spaces. However, exterior façades trigger different emotional responses due to their interaction with environmental lighting, landscape context and public visibility. This gap in knowledge is particularly relevant for rural areas, where buildings often serve as visual landmarks within the landscape and contribute to the local identity (Høibø et al., 2018). Furthermore, existing immersive virtual reality (VR) studies in architectural contexts predominantly feature urban case studies, while rural settings are comparatively underrepresented (Safikhani et al., 2022; Schewenius & Wallhagen, 2024).

This thesis addresses this research gap by focusing on rural Swiss environments and systematically examining the impact of building façade colors and materials on emotional responses. By using immersive virtual reality simulations, the study enables controlled manipulation of visual variables while maintaining a high level of realistic landscape representation. The findings aim to inform both architectural design practice and planning guidelines for rural areas in Switzerland.

1.2 Objectives and Research Hypotheses

Based on the research goal and the current state of research, the following three Research Questions **(RQ)** were formulated. Each question is accompanied by a corresponding Hypothesis **(H)**, based on current state of research.

1. Color and Arousal

RQ1: How does façade color influence emotional arousal in rural Swiss environments?

H1: Façades of buildings in rural regions of Switzerland with colored surfaces induce higher emotional arousal than neutral surfaces, with cold colors having a calming effect and warm colors having an exciting effect.

2. Material and Valence

RQ2: How does façade material influence emotional responses of building colors?

H2: The emotional response to the color of a building façade is dependent on the material it is placed on, with natural materials evoking more positive emotional responses than higher-processed materials.

3. Rural vs. Urban Backgrounds

RQ3: To what extent does the residential background affect emotional responses toward façade color and material?

H3: Emotional responses to the tested features differ significantly between participants with a rural background and participants with an urban background.

1.3 Scope and Positionality

The scope of this study is limited to rural areas within Switzerland, with a specific focus on emotional responses to façade colors and materials. The thesis concentrates on exterior façades in the broader context of the rural landscape, rather than on detailed architectural elements, in order to capture the overall visual impression. The analysis is grounded in the Swiss regulatory and cultural setting, thus findings are not intended to be universally generalizable.

From a positionality perspective, this thesis is conducted in the field of geovisualization. My academic background lies in GIScience, complemented by professional experience in spatial planning. I have worked on projects at the municipal level which included the formulation of design regulations based on higher-level legislative frameworks. This combination of technical geovisualization skills and planning practice has shaped my interest in examining whether such regulations are scientifically grounded in terms of their aesthetic impact. I do not have a background in architecture and therefore approach the subject from a broader spatial and landscape-oriented perspective, prioritizing the perception of the overall environment rather than technical construction details. In this context, the measurement of emotional responses offers a particularly interesting approach, as it allows the objective assessment of aesthetic perception beyond self-reported preferences. This position has shaped the framing of the research questions, the applied methods and the interpretation of the results.

1.4 Structure

Following the *Introduction* which outlines the research context with the research questions and hypotheses, the *State of Research* chapter provides the theoretical frameworks and related studies. The *Methods* chapter describes the environmental design, experimental setup and data processing procedures, followed by the *Results* chapter, which presents the main findings. These findings are compared with current research and theoretical frameworks in the *Discussion* and answer the research questions and hypotheses. Finally, the *Conclusion* summarizes the key results and highlights potential directions for future research.

2. State of Research

This chapter reviews the conceptual and empirical groundwork that frames the scope, design and interpretation of the findings of this thesis. It consolidates classic theories and recent findings, clarifies assumptions and identifies gaps that motivate this study's design.

2.1 Building Aesthetics

The meaning of beauty in architecture and aesthetic preferences in the design of the built environment have already been explored since classical times (Prieto & Oldenhave, 2021).Vitruvius, a Roman architect of Greek influence, outlines in his *De Architectura* the primary qualities of a building as *ordinatio* (order), *disposito* (arrangement), *distributio* (distribution), *eurythmia* (harmonious proportion), *symmetria* (mathematical proportion) and *decor* (propriety). While the first three relate to the technical aspects of architecture, the latter three describe its aesthetic qualities, which are actively produced in the design process (Manenti, 2019; Scranton, 1974). These concepts of aesthetic qualities in architecture remain a central topic of discussion from antiquity to the present day.

Contemporary researchers, planners and architects continue to investigate principles and classifications of "beauty" in the built environment to answer the question "What gives people pleasure and why?" This inquiry aims to inform human-centered design approaches in the development of buildings, cities and landscapes and is broadly situated within the research field known as *Cognitive Architecture* (Nasar, 1994; Prieto & Oldenhave, 2021; Sussman & Hollander, 2021).

Both perceptual and cognitive processes elicit in individuals the aesthetic experience of architectural design (Lang, 1987). As emphasized by Weber (1995), perception is a physical process that functions autonomously and independently of an individual's internal cognitive processes such as imagination, memory or recognition. Thus, certain architectural designs provoke pleasurable responses due to the perceived sense of order (Da Luz Reis & Dias Lay, 2010). In this context, cognition refers to the judgement of architectural attributes based on their perceptual qualities (Nasar, 1994). The emotional mechanisms involved are defined in detail in Section 2.3.

Various researchers have attempted to categorize the aesthetic dimensions. For instance, Nasar (1994) distinguished between the *structure of forms* and the *content of forms*. The structure of forms refers to formal aesthetic elements (e.g. shape, proportion, scale, color or illumination), while the content of forms covers the meanings, associations and functions that are attached to the former elements (e.g. symbolic meanings, historical or cultural references or personal and social associations).

In a similar manner, Prieto & Oldenhave (2021) distinguished between the *intrinsic* and the *extrinsic* dimension of aesthetics. Intrinsic aspects refer to criteria involving mental connections and familiarity that the observer has with the qualities of a building. Extrinsic aspects pertain to the physical characteristics of the built environment. The significance of the intrinsic dimension is supported by studies finding differences among architects' and other experts' evaluations of building façade aesthetics compared to those of laypersons (Ghomeshi & Jusan, 2013; Gifford et al., 2000). On the other hand, the extrinsic dimension includes the categories composition, plastic, detail design and character, and expression (Prieto & Oldenhave, 2021).

Under compositional aspects fall elements such as proportion, rhythm, or stratification. For instance, Keshtkaran et al. (2017) examined aesthetic preferences in high-rise buildings, with the result that people preferred distinctive factors (such as asymmetry or complexity) over basic factors (like balance, symmetry or regularity). The plastic subgroup includes attributes like material expression and surface qualities such as texture, roughness and depth. In studies, wood as a building material is often perceived as aesthetically pleasing because it serves as an immaterial bearer of cultural meaning (Adam et al., 2023). Detail design and character include factors such as refinement and simplicity. Studies have shown that decorated, articulated façades (Frewald, 1989) and ornateness (Nasar, 1983) enhance visual preference. Lastly, the character and expression subgroup contains façade attributes like amazement or color. For example, several studies have examined how the use of color supports the communicative potential of architecture (Meerwein et al., 2007; Mikellides, 2012).

The interplay between these dimensions and subcategories constitutes an essential part of the broader research field of cognitive architecture. How the relationship between the intrinsic and extrinsic dimensions – or equivalently between the content and structure of forms – manifests in practice is illustrated for example by Sussman and Hollander (2021). Their main claim is that the brain reconstructs reality according to its own biological principles – the intrinsic dimension. This motivation leads to the emergence of building patterns – the extrinsic dimension – that resemble faces even when created unintentionally. Humans tend to replicate patterns they know the best and such forms are more likely to capture attention and evoke emotional engagement. Ultimately, this contributes to greater aesthetic appreciation and well-being in the built environment.

On the extrinsic or content-related dimension of cognitive architecture, this thesis focuses on the two stimuli of color and material. Their fundamental principles and emotional influences within the field of Cognitive Architecture will be examined in further detail in Section 2.4 and 2.5. On the intrinsic dimension, potential differences between people's rural or urban background will be analyzed.

2.2 Rurality

The geographical setting of this thesis is rural Switzerland. The term *rural* refers not only to a geographical place, but also to an imaginative space, imbued with cultural meaning, often embodied in certain material objects and lifestyles that some people desire (Cloke, 2006). Accordingly, not only is it important to distinguish between rural and urban residential areas, but also what people *perceive* as rural or urban (Ströbele & Hunziker, 2017).

2.2.1 Rural Areas in Switzerland

Various official publications by the Swiss Federal Statistical Office (FSO; German: *Bundesamt für Statistik,* BFS) have established a hierarchical topology of Swiss municipalities based on quantitative spatial criteria (Bundesamt für Statistik (BFS), 2014, 2017, 2024). These classifications are updated periodically and reflect current conditions. Currently, two typology reports of Swiss municipalities, from 2012 and 2020, exist.

In both the 2012 and 2020 decision trees, the first step identified whether municipalities have an "urban character". According to the typology of the FSO, municipalities are classified with an urban character if they belong to an agglomeration core – with at least 20,000 inhabitants – or its agglomeration belt, where a significant share of the resident workforce commutes to the core (Bundesamt für Statistik (BFS), 2024). In a second tier, those areas are then assigned to one of nine categories, according to data of density, population size and accessibility. A third tier further subdivides these categories into 25 socio-economic types (Bundesamt für Statistik (BFS), 2014, 2017). The inclusion of peri-urban categories softened the strict urban-rural dichotomy (Bundesamt für Statistik (BFS), 2014).

For the scope of this thesis, attention is limited to the nine second-tier categories, with the three rural types - rural central municipality, rural centrally located municipality, and rural peripheral municipality – representing the geographically rural areas of Switzerland. According to the most recent spatial typology of 2020, Switzerland contains 691 rural municipalities. Geographically, most rural municipalities are located in Pre-Alpine and Alpine regions, in the Jura and around Lake Constance (Thurgau) whereas the Swiss Midland is dominated by urban und peri-urban municipalities. By land area, rural municipalities occupy the majority of Swiss territory, and account for about 25 percent of the national population (Bundesamt für Statistik (BFS), 2024). Figure 1 illustrates the nine second-tier categories as mentioned before, with rural municipalities in green. However, in terms of both population and land area, attention to the development of these rural areas is still important. Despite the national policy (RPG) emphasis on densifying already urban centers, rural areas still warrant consideration (Bundesamt für Raumentwicklung (ARE), 2024).

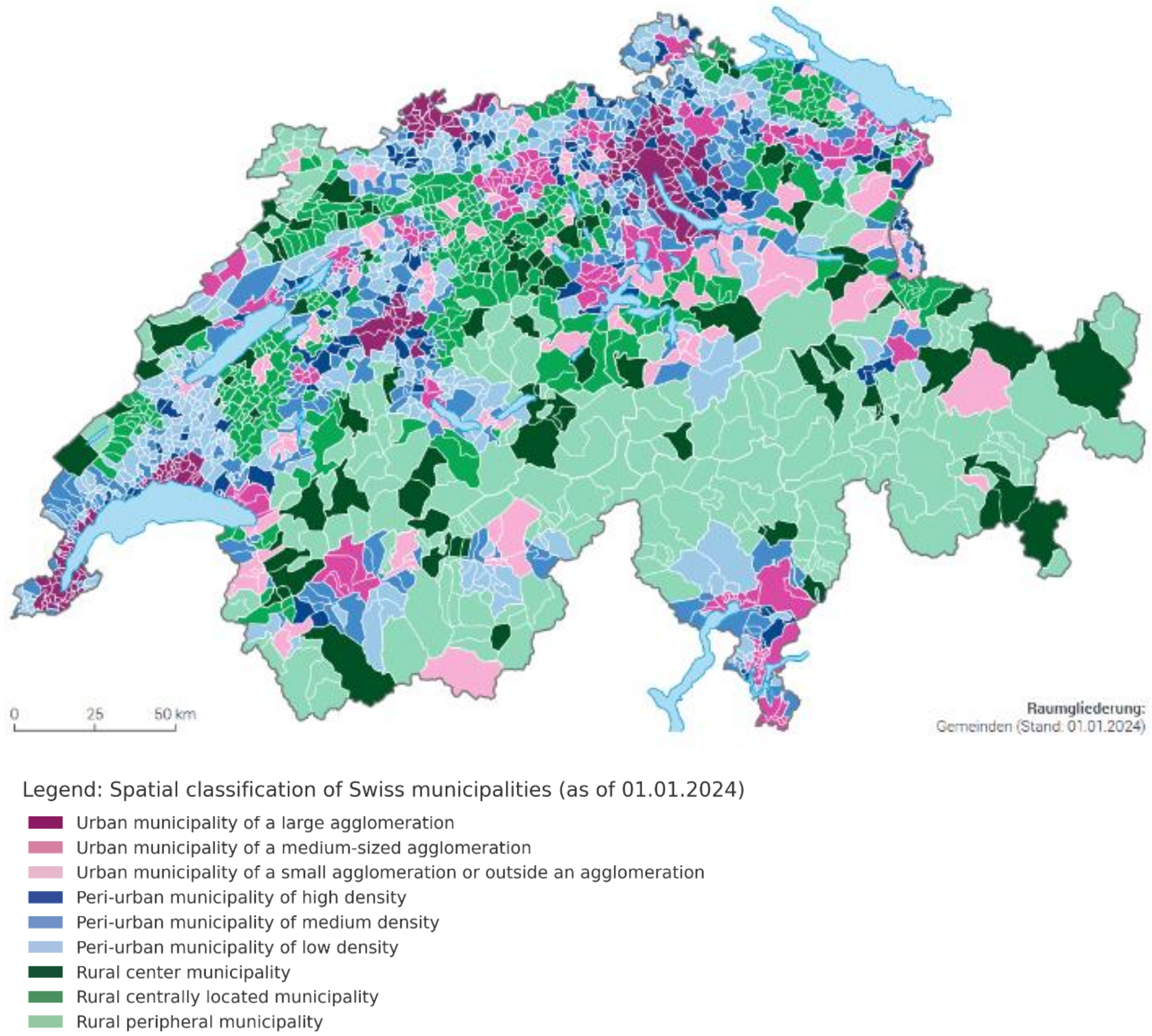

Figure 1: Municipality Typology 2020 with 9 Categories (Bundesamt für Statistik (BFS), 2024)

2.2.2 The Urban–Rural Divide in Switzerland

Many researchers nowadays assume that the sign "rurality" and its signification (the meaning of rurality) are increasingly divorced from their referent (the rural geographical space). Thus, socially constructed notions of rurality have become even more detached from their functional, geographical space (Cloke, 2006; Csurgó et al., 2023). However, in Swiss media, two-thirds of the Swiss population perceive a significant divide between city and countryside which, contrary to Cloke, is not narrowing but deepening (Hermann et al., 2023). Accordingly, this so-called *Stadt–Land Graben* (urban–rural divide) remains a widely discussed and researched topic (Hermann et al., 2021, 2023; Maxwell, 2020).

The urban–rural divide in Switzerland emerged not only from the economic dimension of agricultural protection, but also from different values and lifestyles. Consequently, the place of living can function as a social identity that shapes the behavior and attitudes of the inhabitants (Zumbrunn, 2024). The divide is mostly visible in political preferences. While urban municipalities tend to vote progressive-liberal and left-leaning, rural municipalities are more conservative and right-leaning. The largest urban–rural gaps recently occurred in agricultural policies. For example, the largest difference in voting happened during the 2022 popular initiative against "Massentierhaltung" (factory farming) making it one of the top five initiatives since 1981 in terms of voting difference between the rural and urban population (Hermann et al., 2023). Yet this pattern is not universal. A study by El Benni et al. (2025) demonstrated that, when accounting for interactions among food prices and agri-environmental goals, place of residence alone did not predict agricultural policy preferences. Thus, the urban-rural divide remains complex and not fully understood.

A further complexity arises from people's own landscape perception. Although only about 25 percent of the Swiss population live in rural municipalities, 32 percent of respondents in a study by Hermann et al. (2021) identified their municipality of residence as rural. Moreover, most respondents regarded their municipalities as a hybrid form of urban and rural. In other words, a great part of the Swiss population consider their residence as rural even when official classifications assign it to a (peri-) urban category (see 2.2.1). This tendency is reinforced by contemporary planning policies that blur the boundaries between urban, suburban and rural areas by bringing urban transformations into the countryside and vice versa (Nüssli & Schmid, 2016).

Turning to landscape aesthetics, existing literature demonstrates clear differences based on the people's place of residence. Wartmann et al. (2021) wrote that "the length of residence in a region was positively related to ratings, suggesting between familiarity or place attachment to how people assess landscapes (p. 7)". Moreover, this preferences vary by topography (e.g. valley vs. hillside) or housing type (high-rise vs. single-family home). Ströbele and Hunziker (2017) reported similar results. According to them, people associated particular landscape elements and settlement structure with rural or urban environments and showed stronger aesthetic preferences for the landscapes in which they lived. The fact that many residents perceived their environment as rural, despite official urban classifications, underscored a widespread preference for rural landscape characteristics in Switzerland. This preference is supported by the results of Hermann et al. (2023), that the prevalence of concrete – which can be seen as a proxy for urbanization – in Switzerland was widely regarded as excessive.

In conclusion, the literature confirms the existence of a pronounced urban–rural divide in Switzerland that extends to the perceptions of landscape aesthetics. However, because many people perceive their own residential background as more rural than official typologies suggest, research still needs to account these subjective identities. Therefore, understanding the urban–rural divide is crucial to identify interacting factors that shape Swiss notions of rural landscapes.

2.3.3 Rural Planning Regulations in Switzerland

Spatial planning in Switzerland is organized on three interrelated levels. At the federal level, cross-cantonal issues are dealt with through instruments and guidelines that apply uniformly across the country. This includes the maintenance of federal inventories such as the "Federal Inventory of Heritage Sites" (*Bundesinventar der Schützenswerten Ortsbilder der Schweiz,* ISOS) or the "Federal Inventory of Landscapes and Natural Monuments" (*Bundesinventar Landschaften und Naturdenkmälern,* BLN), as well as provisions of the Spatial Planning Act, such as regulations of construction outside building zones, or the construction of national roads. At the cantonal level, the principal tool is the "Richtplan" which includes cantonal policies like forest zones, watercourse corridors, cantonal streets or cantonal development areas. Finally at the municipal level, land-use plans (*Nutzungsplanungen*) implement the higher-level directives in parcel–specific terms. Boundaries of residential, industrial or mixed zones are precisely delineated and design regulations are set. Through continual coordination and mutual adjustment, these three levels ensure coherent, sustainable spatial development throughout Switzerland (Bundesamt für Raumentwicklung (ARE), 2024; Bundesgesetz Vom 22. Juni 1979 Über Die Raumplanung, 2019).

The promotion of high-quality building culture in rural region is primarily the responsibility of the cantons, supported by federal foundations such as the “Strategy for Building Culture” *(Strategie Baukultur)*. This strategy mandates that both new construction and alterations within villages as well as interventions in the open landscape meet equally rigorous aesthetic, ecological and social standards through binding instruments like federal and cantonal planning ordinances. Complementary technical guidelines assist cantons and municipalities in designing characteristic rural structures like stables, barns and farmhouses in ways that respect local materials, traditional construction methods and the surrounding landscapes (Bundesamt für Kultur (BAK), 2020).

For example, the canton of Aargau has published a “Guideline for Color and Material Selection in Rural Contexts”, which recommends that architectural paints should be traditionally used in earthy or stony hues. The guideline specifically advises against light, cool colors (“sky blue”, “lemon yellow”) as well as creamy pastels (“vanilla”, “apricot”). Bold, saturated tones must be employed with caution, and pure white, though striking in urban settings, may appear incongruous in certain rural landscapes. In terms of cladding, untreated timber is to be prioritized to maintain material authenticity and visual harmony (Departement Bau, Verkehr und Umwelt, Kanton Aargau, 2018).

Similarly, the guideline “Open Space in the Village” (*Freiraum im Dorf*) offers a compendium of best practices for conserving and integrating historic gardens, plazas and heritage-listed buildings into village fabric. It emphasizes the delicate treatment of transition zones between built-up areas and adjacent agricultural land, and highlights strict cantonal requirements for construction outside designated building zones (Schweizer Heimatschutz, 2018). For instance, the Canton of Glarus prescribes that timber façades remain untreated or, if plastered, finished only in subdued whites and greys, ensuring that traditional methods, local design motifs and regional color palettes remain legible in the landscape (Kanton Glarus, 2022).

Overall, spatial planning in Switzerland’s rural regions is shaped by the three-tiered planning system. The Confederation establishes overarching policy and normative frameworks, cantons adapt and specify these policies for their unique rural contexts via structure plans and technical guidelines, and municipalities implement them through detailed zoning regulations. By setting such precise parameters, these guidelines not only promote a coherent, high-quality building culture but also aim to protect the unique character of these rural areas.

2.3 Emotion

In this chapter the term *Emotion* is conceptually situated within its theoretical foundations, followed by empirical methods that are used to measure its dimensions. Emotions are central to this thesis, as they represent the key responses through which Color and Material in building aesthetics are evaluated.

2.3.1 Theoretical Concepts of Emotion

Among scientists there is no existing consensus about a definition of emotion. Emotions are inherently abstract and subjective, remaining difficult to define, measure and systematically analyze (Magalhães et al., 2023). Various theories exist, regarding how emotions are caused, their dimensions and where they originate within the human body. As scientific understanding of the underlying physiological mechanisms continues to grow, a clear (re)definition of terms describing behavioral processes has been repeatedly emphasized (White, 1989). Thus, the conceptual clarity of the term Emotion is essential for identifying and examining the relevant psychological variables that will be measured in the context of this thesis.

Pioneers of describing emotions were Carl Georg Lange & William James (1922) with their widely recognized *James–Lange Theory*. With their core idea that emotion is the perception of bodily changes in response to a stimulus, they reversed the common belief that the body change happens because of an emotion (Cannon, 1987; McFarlane, 2024). For instance, people don't cry because they feel sad, they are crying first and feel then sad (McFarlane, 2024). Following this approach, theorists claimed that physiological reactions like a racing heart or sweaty palms are regulated by the vasomotor system and form the emotional experience such as fear, joy or anger (Ratcliffe, 2005). This perspective broadens the understanding of emotions, emphasizing that they are not solely biological but also deeply embedded in our interactions with the environment (McFarlane, 2024).

In contrast, according to Walter Cannon (1987) "the visceral changes are relatively insensitive structures (p. 573)" and "too slow to be a source of emotional feeling (p. 574)". For example, in experiments with animals with disconnected autonomic systems, Cannon (1987) proved that emotions can still occur without any bodily feedback. Following these experimental findings Cannon co-developed together with Philip Bard the *Cannon–Bard Theory*. They suggested that emotions can be traced back from the thalamus in the brain, which sends signals simultaneously to the cortex (leading to conscious emotion) and to the autonomic nervous system (leading to physiological arousal) (McFarlane, 2024). With that theoretical approach, fast and intense emotions can be explained, as well as why distinct emotions feel different even with similar bodily changes. For example, standing on a cliff and witnessing a thrilling goal may involve a racing heart and adrenaline surge, even though the felt emotions differ between fear (cliff situation) and excitement (goal situation) (Cannon, 1987).

Despite its empirical validation through experiments, Loaiza (2021) argues that the Cannon–Bard Theory might oversimplify the nature of emotions and fails to consider cultural influences. Figure 2 juxtaposes the emotional processes proposed by the James–Lange Theory and the Cannon–Bard Theory.

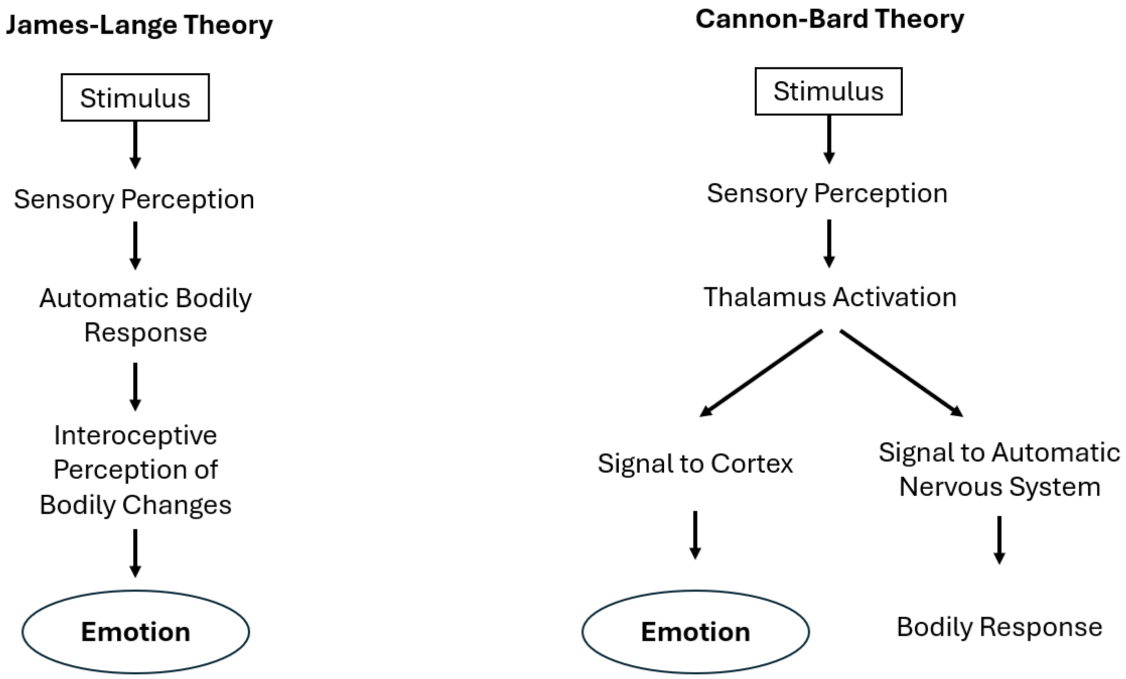

Figure 2: Comparison of the James-Lange and Cannon-Bard Theories of Emotion Processing. Own figure based on Lange & James (1922) and Cannon (1987)

Building upon earlier physiological models, the *Schachter–Singer Two–Factor Theory of Emotion* takes the critics of Loaiza into account and defines emotion as not only a state of physiological arousal but also of cognition appropriate to its state of arousal (Schachter & Singer, 1962). Thus, the cognitive appraisal of a situation is essential to the actual emotion experienced (McFarlane, 2024).

What all the theories discussed so far have in common, despite their differing emphases on physiology or cognition is the factor that emotions constitute mental states, even when somatic signals participate in this mental experience (Cabanac, 2002). Cabanac (2002) proposed a shared foundation by defining *emotion* as "any mental experience with high intensity and high hedonic content (pleasure / displeasure) (p. 76)". Following this definition, it clarifies several controversies, whether emotion is primary, independent of cognition or always dependent on cognition.

The most prominent common factor explaining emotional variation is *affect.* As a central aspect of mind, affect is subjectively experienced through emotions, moods and other feeling states (Kuppens et al., 2013). Affect means "to produce change" and refers to the influence of the mind in a way that is linked to the bodily processes. In the science of emotion, affect is a general term with addressing anything emotional (Feldmann Barrett & Bliss-Moreau, 2009). Wilhelm Wundt (1987), described affect with people being likely "never in a state entirely free from feeling (p. 92)". Thus, the simple feeling state, which a person always experiences is the "affective tone of a sensation (Wundt, 1987, p. 36)." The affective states can be distinguished in three core dimensions – pleasantness / unpleasantness (*valence*), arousing / subduing (*arousal*) and strain / relaxation (*intensity*). Combined with other mental elements it can then become an emotion. Consequently, affect is distinct from emotion. While affect refers to the pure, continuous feeling like feeling uncomfortable (negative valence, high arousal) emotion is the interpreted form of a feeling in the special context of the stimuli, for example having fear (interpreted affect + context) (Feldmann Barrett & Bliss-Moreau, 2009).

Building on the concept of affect, Russell (1980) developed the *Circumplex Model of Affect*. He stated that affective states are best represented as a circle in a two-dimensional space, with the North–South axis representing the arousal dimension and the East–West axis representing the valence dimension, with distance from the origin representing their intensities. Together, the degree of valence and arousal form a unified state, so even if it is possible to focus on only one property, affect always includes both. In other words, people cannot feel pleasant or unpleasant without any amount of arousal. Russell (1980) placed in the two–dimensional circle 28 affect words, like "relaxed", "tired", "afraid" or "happy", based on their combination of valence and arousal. In Figure 3 a simplified version according to the Circumplex Model of Affect from Russell, additional with implications by Feldmann Barret & Bliss-Moreau (2009) and Kensinger (2004).

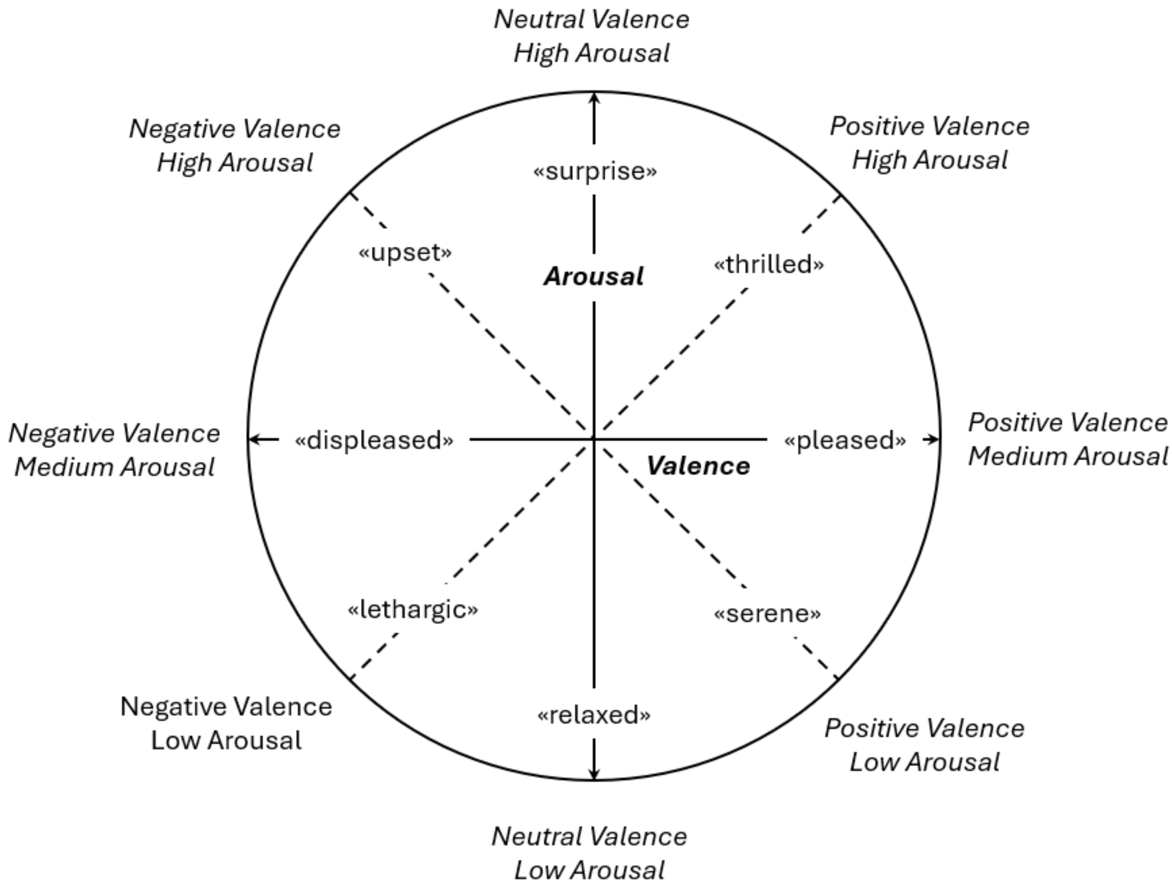

Figure 3: Circumplex Model of Affect. Own illustration based on Russell (1980), Feldman Barret & Bliss-Moreau (2009) and Kensinger (2004)

However, this model is not without criticism. Various studies have shown that the relationship between valence and arousal differs among individuals. For some participants, feeling good means feeling excited with a high positive arousal, while for others feeling good means feeling relaxed. Still other individuals experience arousal and valence as more independent dimensions. While arousal is strongly linked to physiological responses, the connection to valence remains less clearly understood (Harvey, 2025).

Based on the theories and their characteristics mentioned in this chapter, I define *Emotion* as follows:

"Emotion is an intense mental state, created by the psychological and physiological interpretation of affective stimuli. It reflects an interpreted variation in arousal and valence, shaped by an individual's prior experiences, cognitive appraisal and environmental context."

According to this definition, measuring specific physiological and psychological variables enables the empirical investigation of emotional states within the scope of this study.

2.3.2 Emotional Measuring Methods

Various methodologies exist for assessing human emotion, each selected according to the study's objectives. Broadly, these methods fall into two categories. Objective or physiological and subjective measures. Physiological assessments capture unconscious, affect-driven bodily reactions, for example metrics such as heart-rate variability, Electrodermal Activity (EDA), and eye-tracking measures (Magalhães et al., 2023). These methods typically index the arousal dimension, since most researchers agree that valence cannot be reliably inferred from autonomic activity alone (Posada-Quintero & Chon, 2020).

By contrast, subjective measures are employed to quantify emotions through self-report instruments. Verbal and written questionnaires and pictorial rating systems allow participants to articulate their experienced emotions. Among these, the *Self-Assessment Manikin (SAM)* remains one of the most universally adopted tools for capturing both arousal and valence without reliance on language (Bradley & Lang, 1994; Morris, 1995).

By integrating both physiological and subjective methods, a *mixed-methods* approach yields a more comprehensive depiction of the human emotional state (Magalhães et al., 2023). In the present thesis, EDA was recorded to index the arousal dimension, and SAM and a post-hoc questionnaire to capture subjective arousal and valence (see Chapter 3.3). The following sections describe the theoretical background of these methods.

Electrodermal Activity EDA

EDA also known as Galvanic Skin Response (GSR) is a measurement of fluctuations in skin conductance arising from sweat-gland activity, thereby reflecting changes in the skin's electrical conductivity (Harvey, 2025; Healey, 2015; Posada-Quintero & Chon, 2020). Although sweat glands function chiefly in thermoregulation, those located on the palmar and plantar surface of hands and feet are particularly responsive to emotion-evoked stimuli rather than to thermal changes alone (Greenfield & Sternbach, 1972). Consistently, EDA has been shown to distinguish quantitative degrees of activation along the arousal scale from calmness to excitement (Harvey, 2025; Healey, 2015). This autonomic response is mediated unconsciously by the neurotransmitter acetylcholine, activated by the sympathetic branch of the autonomic nervous system (Christie, 1981).

In experimental settings, EDA may be recorded via electrodes on fingers, while for ambulatory or field studies, wearable EDA sensors, often integrated into wristbands or smartwatches, can also be worn outside of a laboratory. However, interindividual variability in sweat-gland responsiveness due to personal physiology, requires measurement of a baseline in resting state prior to stimulus presentation. Subsequent deviations from the baseline then accurately reflect stimulus-induced arousal (Harvey, 2025).

Raw EDA signals are typically decomposed into two complementary components. Phasic responses or *skin-conductance responses* (SCRs) refer to specific events like “startle-like” stimuli reflecting a rapid peak with small degree of latency from stimulus onset. Tonic responses such as the *area under the curve (*AUC) represent longer-term trends with slowly changing responses to stimuli such as ambient environmental conditions (Braithwaite et al., 2013). Ambulatory EDA recordings are particularly susceptible to motion artifacts. Consequently these motion errors need to be filtered out before the analysis, which is usually performed manually (Harvey, 2025).

A further limitation in EDA research is the typical small sample size of participants. Many studies varied between 10-15 (Berger & Dörrzapf, 2018; Chrisinger & King, 2018; Winz et al., 2022) and 30 participants (Lee, 2022; Pykett et al., 2020). However, the mentioned studies demonstrate robust EDA effects in the context of building and landscape aesthetics, often under usage of virtual reality. For example, Pykett et al. (2020) analyzed SCRs to VR-simulated urban green spaces, Lee (2022) recorded EDA during VR architectural walkthroughs while Berger & Dörrzapf (2018) recorded EDA during heritage building tours. Collectively, these applications underscore EDA’s suitability for capturing rapid autonomic responses to virtual environmental stimuli, thereby justifying its central role in the present thesis.

Subjective measurements

The complexity of emotions has led to the development of numerous subjective measurement formats (Morris, 1995). However, reliance on language-based scales hinder assessment in populations with limited linguistic proficiency, such as young children or individuals with aphasia. To overcome these language barrier, Bradley & Lang (1994) developed the Self–Assessment Manikin (SAM), a picture–oriented instrument which directly represents Russell’s affective dimensions without requiring verbal labels. On the pleasure dimension, SAM depicts pictures from a broadly smiling figure to a frowning, unhappy figure. On the arousal dimension it ranges from an excited, wide-eyed figure to a relaxed sleepy figure and on the dominance dimension SAM represents control through change in figure size (Bradley & Lang, 1994; Morris, 1995).

Although the original SAM employed three separate 9-point scales, many contemporary studies have adopted simplified versions, often reducing the number of response steps or omitting the dominance scale entirely, while retaining robust validity for pleasure and arousal measurement (Nandy et al., 2023; Simoës-Perlant et al., 2018). Furthermore, SAM rating of pleasure and arousal frequently covary with physiological indices of emotional reactivity, thereby providing a multidimensional understanding of affective responses to tested stimuli (Bradley & Lang, 1994).

One major advantage of SAM is its rapid intuitive application. Participants can complete ratings on SAM scales in less than 15 seconds, enabling the test of numerous stimuli in a short time. This efficiency facilitates precise measurement of state affect in experimental contexts. Furthermore SAM demonstrates cross-cultural invariance in emotional interpretation. Several studies have also reported higher participant interest and engagement in SAM rating versus verbal self-reports which leady to lower measurement errors when using SAM (Morris, 1995).

Consequently, SAM has become a widely used instrument in diverse research domains, including Cognitive Architecture (e.g. Naghibi Rad et al., 2019) VR experiments (Xie et al., 2020) or both combined (Lanini-Maggi et al., 2024). Its efficacy in capturing rapid fluctuations in both pleasure and arousal makes SAM especially well-suited for assessing emotional responses within immersive virtual-reality environments.

Retrospective questionnaires of emotions can meaningfully complement measures like the SAM. Hadinejad et al. (2018) demonstrated that post-hoc questionnaires provide critical contextual information of understanding why a given stimulus elicits a particular pattern of autonomic response. Diener and Emmons (1984) first established that conventional questionnaires of well-being correlate only moderately with *ecological momentary assessments* (EMA). Subsequently, EMA research has confirmed this gap, for instance Solhan et al. (2009) reported only modest to moderate agreement between trait questionnaire scores and EMA–derived affective indices. Accordingly, Ebner-Priemer & Trull (2009) advocated for the combined use of trait and state measures, arguing that such integration captures both enduring dispositions and transient emotional reactions, yielding more robust preferences of participants than either method alone. Illustrative applications of post-hoc questionnaires in the field of aesthetic experiences were developed for instance by Kenett et al. (2023) and in combination with architecture by Schindler et al. (2017).

2.4 Color Aesthetics

Color represents the first key stimulus on façades examined in this thesis (**RQ1**). The crucial role of color in rural building aesthetics is reflected in Swiss guidelines such as the "Strategie Baukultur" or its incorporation into building and zoning guidelines of municipalities (Der Bundesrat, 2024). Color can evoke a spectrum of emotional responses, varying both in arousal and in valence, based on its fundamental perceptual dimensions.

2.4.1 Dimensions of Color and Color Models

Colors can be defined by the three perceptual dimensions of *hue, saturation* and *lightness*. *Hue* refers to the attribute by which one color is distinguished from another and corresponds physically to its dominant wavelength. All perceivable hues are mixtures or proportions of the six elemental spectral colors – Red, Orange, Yellow, Green, Blue and Violet. Achromatic Stimuli are White, Gray and Black. These contain no spectral hue and are perceived colorless. *Saturation* measures a color's purity or strength, indicating how "vivid" it appears compared to a grayed down color. The third attribute, *Lightness,* quantifies the fraction of light reflected from the colors surface. It should not be confused with "Brightness" which properly refers to the source intensity – and means "highly saturated" (Meerwein et al., 2007). Together, these three attributes of color are divided into luminance (lightness) and chrominance (hue and saturation). Color models map these attributes as coordinates in a three-dimensional space (Ibraheem et al., 2012).

In general, color models are distinguished into additive and subtractive systems. According to Wyszecki & Stiles (1982), *additive mixture* refers to combining light stimuli. By combining wavelengths of colors, more light is added, and the resulting color becomes brighter and moves towards White. In contrast, *subtractive mixture* involves combining inks, dyes or filters that absorb parts of the light spectrum. Each added layer removes more light, so the resulting color gets darker and shifts towards black. These mixing principles lead to different achievable color gamut for the corresponding model. An example for an additive system is *RGB* and for a subtractive system *CMYK*.

Color models are further classified as device-dependent or device-independent. Dependence (e.g. RGB, CMY) refers to numeric values tied directly to specific hardware characteristics like monitor phosphors or ink densities. Independence defines colors via standardized observer functions and illuminants (e.g. Munsell). Additionally, user-oriented models such as HSV, HSL and HIS provide an interface between human perception and device signals (Ibraheem et al., 2012). In this thesis, the color stimuli are rendered using the standardized RGB (sRGB) model, as explained in detail below.

(s)RGB Color Model

Human color vision is trichromatic, consequently three color primaries allow the production of a wide range of colors. An additive system combining red, green and blue primaries achieves the largest possible gamut for three primaries, representing the RGB color space, with origins traced back to the *Young–Helmholtz theory of trichromatic color vision* in the early 19^{th} century (Westland & Cheung, 2015).

The RGB color space is commonly depicted as a unit cube with normalized channel value from 0 to 1. The x–, y– and z–axes represent the three color primaries with Black at (0, 0, 0), White at (1, 1, 1) and secondary hues Cyan (Green + Blue), Magenta (Red + Blue) and Yellow (Red + Green) along the edges (Ibraheem et al., 2012; Westland & Cheung, 2015).

However, no single RGB color space has reached universal acceptance. Instead, a variety of spaces, each with different standards and primaries have evolved over time to meet evolving consumer demands, professional requirements and technological advances (Westland & Cheung, 2015). Addressing this problem, Microsoft and HP jointly introduced the sRGB standard in 1996 (IEC 61966-2-1), which has since become ubiquitous across Microsoft operating systems, HP hardware and the Internet (Anderson et al., 1996). *Unreal Engine*, the software used to render the VR environments in this thesis, uses sRGB as default for on-screen color reproduction, although it also supports rendering in alternative color spaces (Epic Games, 2025b).

sRGB defines a precise gamma-encoding curve to transform linear RGB values into display-ready signals. Since CRT monitors naturally exhibit a non-linear relationship between digital input and emitted luminance, the sRGB gamma curve corrects this non-linearity. Thereby, visible banding is reduced and sRGB-encoded images appear colorimetrically faithful and visually balanced on typical displays (Anderson et al., 1996).

One drawback of sRGB transformation is its relatively limited gamut, especially in the blue-green region. This can exclude certain hues reproducible in printing and thus is avoided by some professionals (Westland & Cheung, 2015). *Figure* 4 illustrates the RGB color space and Figure 5 the extent of the sRGB gamut after the Gamma correction. Nevertheless, because the experimental study in this thesis focuses exclusively on digital, on-screen presentation rather than printed output, the sRGB offers sufficient coverage and consistency for all experimental color stimuli.

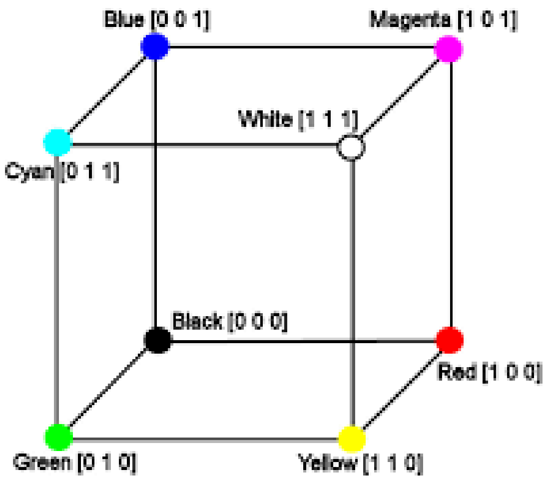

Figure 4: RGB Color Cube *(Westland & Cheung, 2015)*

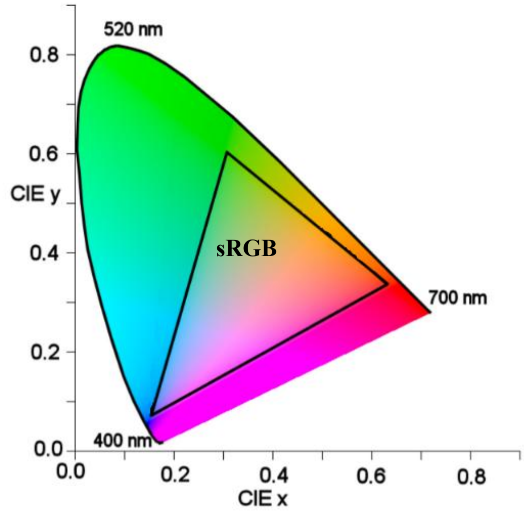

Figure 5: sRGB Color Gamut according to Westland & Cheung (2015)

2.4.2 Emotions of Colors

The notion that color affects human emotion is not a new subject in research. This relationship has been discussed and investigated since the early 19th century. Well known historical concepts such as *Goethe's Farbenleere (Theory of Colors)* and Le Corbusier's *Polychromie Architecture* have significantly influenced how color has been perceived over time. Although these theories are several decades or even centuries old, their fundamental principles continue to be implemented in architectural practice today and still shape contemporary aesthetic understanding (De Heer, 2009; Manav, 2017).

However, more recent studies question and refine these earlier perspectives. They explore in more detail, how specific emotional responses are associated with different colors under varying conditions, such as lighting situations, urban environments or differing cultural contexts across countries. Recent advancements in technology have expanded the methodological scope to understand the complex interaction between the three dimensions of color and the dimensions of emotional responses, offering a nuanced understanding of how emotional responses to color are influenced by environmental factors, cultural backgrounds and personal experience.

Corbusier's Polychromie Architecturale

Charles-Édouard Jeanneret, better known as Le Corbusier, was a prominent Swiss architect and painter, who played a key role in early 20th-century modernism. Together with Amédée Ozenfant, he co-founded the Purism movement, combining composition and artistic theories that would heavily influence his architectural philosophy. Central to his design concepts was a standardized, emotionally responsive approach to color in architecture. Le Corbusier's intention was to evoke "constant" human reactions to spatial environments through controlled color usage (Shannon & Shannon, 2020). He articulated this notion with the words: "The search for space, for light, for joy, for strength, for serenity, invites us to call for color, daughter of light (Shannon & Shannon, 2020, p. 36)."

In his architectural color theory, Le Corbusier formulated three key principles. Firstly, color modifies space, secondly color classifies objects, and thirdly color acts physiologically upon humans eliciting strong emotional responses (Serra et al., 2021). Building on these foundations, he developed the manifesto *Polychromie Architecturale* between 1932 and 1933, a milestone of architectural color theory that connects color preference to both individual personality and psychophysical perception (De Heer, 2009; Jaglarz, 2024; Serra et al., 2021; Shannon & Shannon, 2020). According to Serra (2016), Le Corbusier believed that beauty in architecture is governed by universal laws based on rational criteria. Therefore, his color palettes were not intended to encompass all color possibilities, but rather to serve as a controlled system enabling harmonious and architecturally appropriate combinations.

The principles behind these palettes were grounded in emotional differentiation. Le Corbusier categorized color based on their emotional resonance and grouped them by tone and value into either the *light side* or the *shadow side*. Colors on the light side were associated with feelings such as "warmth", "gaiety", violence" and "joy", while those on the shadow side conveyed "freshness", "serenity", "melancholy" and "sadness". In this framework, Blue and Red formed the foundational contrast – blue tones represent the shadow side while red tones represent the light side. This opposition forms a contrast not only visually but also physiologically, psychologically and associative. Accordingly, when aligned with emotional models (see Chapter 2.3.1) Red corresponds to high arousal with high excitement, while Blue evokes low arousal and calming effects. This approach follows Goethe's Farbenlehre, although Le Corbusier substituted Red for Goethe's Yellow as the principal color of the light side (De Heer, 2009).

Furthermore, Le Corbusier distinguished between three functional color categories: constructive colors, dynamic colors and neutral colors. Constructive colors are derived from natural pigments such as Brown, Ochre and Sienna. These earthy tones convey a sense of harmony and contribute to the atmospheric coherence of space. Dynamic colors, such as saturated Red, Ultramarines and vibrant Yellows, generate high visual contrast and provoke strong emotional engagement. Neutral colors serve as transitional or transparent elements, allowing surface modifications without affecting perceived volume or spatial depth. Examples include soft earth tones, Grays or Greens (Jaglarz, 2024).

White held a special role in Le Corbusier's theory. Initially perceived as an absolute value representing purity, neutrality and universal clarity, its role shifted over time. Later, White came to be regarded as a relative value, not a color in itself but a background enabling other color to acquire meaning (Sendai & Suzuki, 2004). This shift reframed White as an organizing element that established the emotional hierarchy of all other hues (De Heer, 2009). Figure 6 shows an example of a building by Le Corbusier with the Pavillon Le Corbusier in Zurich.

These color principles for spatial perception, light and emotion lead to the development of the *Salubra color palette*. Instead of an open system, it served as a practical manual of well-defined, harmonized combinations intended for architectural use (Serra et al., 2016). The original 1931 collection consisted of 43 color tones and was expanded in 1959 by 20 additional shades, culminating in a color palette of 63 color shades referred to as "the harmonized colors for architecture" (Shannon & Shannon, 2020). Figure 7 displays the color shades in this color palette.

Figure 6: Pavillon Le Corbusier, Zurich. Photograph by M. Proske. Used with permission

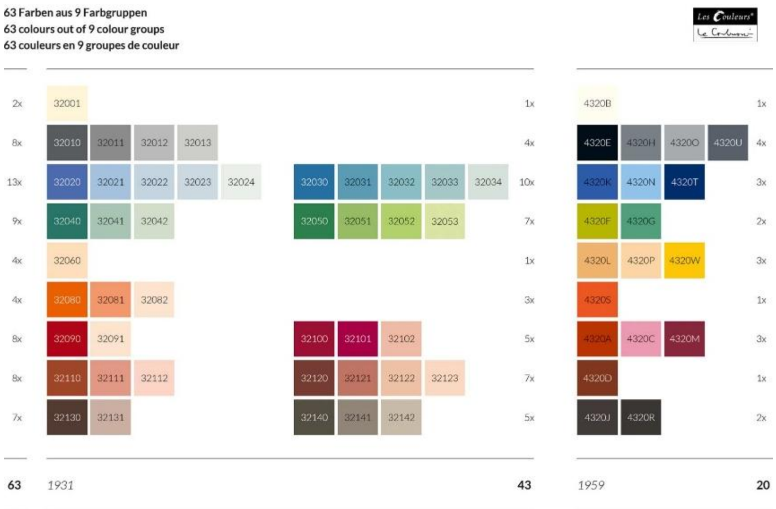

Figure 7: Salubra color palette, 63 colors from 9 color groups © FLC-ADAGP-Les-Couleurs-Suisse . Used with permission (Les Couleurs® Le Corbusier, 2025)

In the later stages of his theoretical development, Le Corbusier moved away from his understanding of color as merely an applied surface treatment. Instead, he began to conceptualize color as something intrinsic to the material itself. This paradigm shift infused materials with deeper meaning, elevating them to the status of "color agents". Similar to colors, materials were seen as interactive, responsive elements that engage dynamically with their environment (Sendai & Suzuki, 2004). The emotional impact of materials in architectural design and its interplay with color is further explored in Chapter 2.5.

Contemporary Empirical Approaches to Color and Emotion

Contemporary approaches to color as an aesthetic stimulus increasingly emphasize the context in which color appears. According to Manav (2017), perceiving color involves a complex interplay of conscious and subconscious processes, in which an objective color stimulus elicits an internal subjective response. This reinforces the idea that the experience of color is inherently individual and cannot be universally standardized. Although Le Corbusier's color theory was highly influential and shaped modern architectural thinking for decades, it was largely based on his personal sense of harmony. From today's scientific perspective this appears outdated, as it lacks empirical input from a broader range of subjective experiences. Current research instead aims to incorporate diverse perspectives to determine whether robust, generalizable principles of color in architectural aesthetics can be established. However, current studies focus mostly on interior colors (Lanini-Maggi et al., 2024).

Regarding the emotional dimension of arousal for colors, several studies converge on similar findings. Wang et al. (2024a) found that, within the warm color spectrum, exterior building color combinations involving Red were associated with high arousal levels and were generally linked to emotions such as anger, excitement and passion. Similarly, a VR study of background colors by Shikata and Matsui (2025) linked Red to perceptions of a warning signal, increasing arousal and risk-averse behavior, while Blue evoked calmness. Wang et al. (2024a) also observed that as hues transition from warm to cool, the users' emotions shift from high activity to low activity. Accordingly, Manav (2017) observed that warm–colored exterior façades were associated with "liveliness", "warmth" and "energy", whereas cooler, darker tones evoked feelings of "calm", "noble", "reserved" and "stability". In a CAVE–VR study, Bowser et al. (2022) proved that exposure to a blue virtual room increased both physiological measures (e.g. skin-conductance) and EEG activity, yet participants simultaneously reported a calming, emotionally engaging experience. Especially light, muted blues appeared effective at reducing arousal, being perceived as open and soothing (Naz et al., 2017). However, Whitfield and Slatter (1978) demonstrated that high emotional arousal induced by vivid colors (red, orange) does not necessarily translate into aesthetic preference; thus, greater arousal does not automatically imply higher valence.

On the valence dimension, Radwan (2015) demonstrated that applying color in socially burdened neighborhoods enhanced public perception, reduced crime rates and strengthened community solidarity by making the sense of space more pronounced. While Red increased perceived vitality it also undermined comfort and security. Thus, rating valence remains difficult. Danaci and Kiran (2020) reported that façades in cool tones (Blue, Purple, Green) were generally rated as more attractive. Wang et al. (2024a) further suggested that green and blue spaces, representing "ecological" or "environmental" spaces, positively influenced physiological and psychological health outcomes, enhancing residents' sense of well-being. Bitterman (2018) likewise noted a broad preference for Blue involving building exteriors in Germany as well as Lanini Maggi et al. (2024) in a study of blue pathways at night. By contrast, highly saturated or very bright Reds elicited lower valence ratings. Similar to that, but generalized for all color hues, Chang et al. (2015) advocated the use of hues with reduced saturation, but increased lightness to boost pleasure, as evidenced in Taipei's Wanhua District. Additionally, a study of façade color of old residential buildings in Shanghai demonstrated that high-saturation led to visual fatigue, reducing the users' perception of the building color (Wang et al., 2024b). Similar to Corbusier's work, different studies showed that White improves overall harmony when paired thoughtfully with colors but remains neutral, clean and functionally on its own (Li et al., 2020; Naz et al., 2017). However, a study in rural Spain by Montero-Parejo et al. (2020) stated that White on exterior façades was less rated than colors due to suitability with the environment.

Thus, an important area of research examines the color harmony of buildings in relation to their surroundings. O'Connor (2006) investigated colors on harborside façades in Sydney and revealed that the strongest contrast combination towards the surrounding (Grey / White) received the highest aesthetic preference while in general hue-similar façades (Green / Browns) were judged most harmonious overall. Whitfield and Slatter (1978) stated that harmony is achieved through context-appropriate palettes, for instance warm hues for residences and cooler hues for hospitals. Zhai et al. (2023) corroborated this principle in Shanghai, where residential areas feature higher saturation and industrial zones employ more subdued yet cohesive color schemes.

Cultural background further shapes these perceptions. Although Blue emerges as the most globally liked color, Red is perceived as particularly pleasant in many Asian contexts. For example, Ren et al. (2024) observed that color norms in Chinese urban areas differ from Western aesthetics, with a higher tolerance for bold colors. Associations vary across cultures, for instance Purple signifies luxury in East Asia but cheapness in the United States. This highlights that preferences are learned and culturally constructed (Madden et al., 2000). Even between two cities within the same country, identical color applications can provoke divergent reactions when applied to neighborhoods of differing character (Danaci & Kiran, 2020).

Taken together, contemporary research indicates that Red consistently emerges as the most arousing hue, but its valence can range from stress (negative) to pleasure (positive), depending on context. Blue proves to be broadly calming and conducive to positive mood, particularly with higher lightness and lower saturation. Overall, color harmony depends fundamentally on environmental and cultural factors. Scholars agree that building and planning regulations must address these dimensions, yet individual variability in color perception makes universal guidelines elusive. Moreover, Europe in particular lacks exterior façade–color studies compared to Asia, where most research has been conducted (e.g. in Turkey , Shanghai, East Asia). Additionally, most research has focused on urban design and less on rural environments. As literature has shown that environmental and cultural context strongly influence color perception, this gap remains critical for developing appropriate, locally sensitive color regulations on buildings.

2.5 Material Aesthetics

Material represents the second key stimulus on façades examined in this thesis (**RQ2**). In architecture, material plays a central role. In its narrow, engineering sense it refers to solid building materials, whose main purpose is construction and structural performance. However, in a broader, design-oriented sense, material is understood holistically as *materiality.* That understanding includes the experiential qualities that emerge how materials interact with light, air and the surrounding environment and thereby contribute to the aesthetic value (Löschke, 2016). Accordingly, Bechthold & Weaver (2017) argue that “material science has transformed from a field that explains materials to one that designs materials from the bottom up (p. 1).”

2.5.1 Naturalness of Materials

There is a wide range of building materials, from minimally processed like earth, straw or natural stone to highly processed artificial materials like laminated glass or steel (Bechthold &

Weaver, 2017; Minke, 2025). Contemporary practice increasingly involves interdisciplinary collaboration among architects, engineers and material scientists to develop new material systems and classes. Recent innovation trends focus on the natural look of materials, reflecting evidence of higher aesthetic meaning and preference. In parallel, research and development pursues reduced environmental impact in the manufacture of materials, as it contributes to human perception (Bechthold & Weaver, 2017).

The aesthetic value of natural building materials has a long history. In the 19th century, John Ruskin's *The Seven Lamps of Truth* advocated using materials in accordance with its natural attributes and critiqued the development of capitalistic processes (Hartoonian, 2016). More broadly, Rozin (2006) suggested that perceived naturalness has two foundational components. An instrumental facet that links to health, the senses and the environment and an emotional facet of idealization and imaginative representation. Culturally shared heuristics often imply natural as more moral, more aesthetic, more eco-friendly and more real.

A growing empirical literature supports that image of natural materials. Zhou et al.(2025) reported increased sympathetic responses associated with relaxation and nature affiliation leading to greater comfort in wooden interiors. Aligning with these findings Himes & Busby (2020) concluded that in several studies timber buildings tended to exhibit lower construction-phase emissions than reinforced–concrete buildings, a sustainable attribute that positively influenced perceived aesthetics. Similarly, Marschallek & Jakobsen (2022) demonstrated that in the packaging industry, plastics as proxies for highly processed materials were more often described as "ugly", whereas natural substrates were judged "beautiful". Fell (2010) on interior offices and Burnard et al. (2015) on building exteriors in Finland, Norway and Slovenia reported reduced physiological arousal to wooden façades, consistent with a calming, preferred material impression.

Concurrently, many highly processed materials now imitate naturalness through surface textures to leverage these aesthetic associations. However, Zhang et al. (2023) showed that even when two materials are physically equivalent in performance, participants preferred the natural option, as they have the knowledge about the production processes. At the same time, both consumers and building professional are not always aware of how natural a material truly is. For instance, several concrete additives are derived from natural materials, for example plasticizers are often produced from lignin a wood-sourced biopolymer (Bechthold & Weaver, 2017)

Furthermore, preferences for natural architectural materials are also culture- and context dependent. Høibø et al. (2018) noted that in some cultures or countries wood-based housing is seen as inferior and a material with low social status, while in other countries the traditions for using wood confer prestige and familiarity. In Switzerland, wood as a construction material has a strong cultural history, especially in rural environments (e.g. farmhouses and barns). Typical rural building archetypes include two-part farmhouses comprising a utilitarian wing (e.g. stables, storage for agricultural tools) predominantly in wood and a dwelling wing often realized in concrete (Kanton Glarus, 2022). Representative examples are shown in Figure 8.

Figure 8: Rural farmhouses in Switzerland (Schmiedrued AG). Own photographs

At the same time, much of the empirical work on materiality has been conducted outside architecture proper (e.g. in packaging design). Studies focusing specifically on the exterior of buildings are comparatively rare. Furthermore, some findings show mixed results. Lipovac & Burnard (2020) synthesized studies which mostly did not detect robust differences in stress recovery between architectural material settings and highlighted a frequent absence of complementary measures (affective self-reports, physiological arousal, cognitive performance).

Høibø et al. (2018) further observed that, whereas interior wood is often rated attractive for «harmony", "activity" and "status", exterior material preferences are more strongly driven by functional and safety attributes like "strength, "fire performance" or "sound isulation". These considerations result in favoring of concrete over wood, especially in the context of high-rise buildings. Consequently, although current research suggests that visual wood exposure may yield desirable outcomes in many scenarios, the evidence base remains limited and warrants systematic testing across diverse environmental and architectural conditions.

2.5.2 The Concept of Immateriality

Immaterial architecture designates an approach in which building materials such as wood, stone and concrete are not treated as isolated, static substances but as elements whose aesthetic force emerges through their interaction with the environment (Hill, 2006). In this view, materials are read together with the choreography of light and shadow, patterns of movement, weather and time of day, all of which decisively shape how a surface is aesthetically perceived (Löschke, 2016). Thus, Löschke (2016) equated i*mmateriality* with *atmosphere* and framed it as an intermediary: "It stages human activities in relation to the surrounding world, including the environment, other people, objects, architecture and art (Löschke, 2016, p. 3)." Within such a framing, material aesthetics is a primary driver of perception. Different materials can alter spatial legibility and depth cues, thereby shifting observers' aesthetic appraisal of the façade – and the surrounding space – in meaningful ways.

Building on this conceptual foundation, Mazumdar (2009) articulated three principle experiences of immateriality. First, *sentient experience*, which includes sense-based aspects like light, color, sound, texture, touch, temperature or odor, which in their aggregation compose the ambience of a building scene. Second, *people in place experience* refers to the way furnishings, patterns of use, cultural conventions and social presence transform how a place feels, even when the underlying construction remains unchanged. Third, *numinous experience* refers to affects such as sacredness or solemnity as in religious architecture and memorials.

Seen through this lens, the interaction between material and color is central. Because architectural color represents the appearance of reflected light, perception is inseparable from the optical properties of the carrier material (Manav, 2017). Thus, color is always dependent on the material it is placed on (De Heer, 2009). In other words, materials create the conditions under which immaterial qualities like color arise. Wood, concrete, plaster or metal modulate light reflection and color rendition, shape acoustics through absorption and reflection and affect thermal comfort via surface temperature (Hill, 2006). In line with this, Löschke (2016) emphasizes that the relationship between the immaterial and the material remains one of the most stimulating and enduring subjects in architectural discourse and practice.

While the material side is generally overemphasized in literature, what many people find memorable about architecture frequently resides in the immaterial, achieved through material means (Mazumdar, 2009). There is empirical work that bridges this claim outside the context of architecture. Studies have documented color–material interactions in color appearance across different materials (Giesel & Gegenfurtner, 2010) and shown how surface roughness and illumination jointly alter perceived color (Chae, 2022). However, Manav (2017) pointed out that a large share of studies still operationalize only a single dimension either material or the immaterial like color rather than testing their conjunction, which risks underestimating their combined effects. A related research strand focuses on material perception under varying daylight and time of the day for example Chamilothori et al. (2022) and Wasilewski & Andersen (2025). However, the state of research still primarily treats immateriality at a conceptual level with limited experimental validation (Jones et al., 2013; Mazumdar, 2009). Nevertheless, the available evidence already supports the claim that material properties and immaterial atmospheres are inseparable in shaping building aesthetics.

3. Methods

This chapter outlines the methods of this thesis in three parts: the design of the VR environments, the design of the conducted study with the experimental procedure and the data processing and statistical analysis. Together, these sections describe the selection and implementation of the stimuli, how the experiment was conducted and how the data was prepared and analyzed to answer the three research questions.

3.1 Environmental Design in Virtual Reality

The design of the rural environment was developed from the ground up. 3D data with rural assets exist, for example, the *swissBUILDINGS3D 2.0* dataset is a 3D dataset of all buildings in Switzerland (Bundesamt für Landestopografie swisstopo, 2024) However, 3D rural environments so far have seen limited use in research, as the focus has predominantly been on urban environments. Furthermore, in this study the aim was to design a hypothetical village rather than replicate an existing one, in order to avoid potential bias.

To ensure a realistic representation, a preliminary spatial analysis was conducted to understand how rural Swiss villages are typically structured in terms of building density, land cover and applicable building regulations. Based on the analysis, an initial rural area was modeled in *CityEngine* and subsequently refined in *Unreal Engine*, including selection and adjustment of specific viewpoints as well as the design of the building façades. The final situations were then implemented in the VR experience workflow. The assets used with their references are displayed in detail in Appendix B.

3.1.1 Analysis of Rural Environments

A random selection of Swiss municipalities classified as rural according to the FSO (see Section 2.2.1) was analyzed to obtain core information relevant to landscape and architectural design characteristics (Bundesamt für Statistik (BFS), 2024).

The sample comprised ten municipalities, randomly selected across different cantons, with building ordinances (*Bau– und Nutzungsordnungen*, BNOs, full list in Appendix A), in German language: Ins and Därstetten (Bern), Arosa (Graubünden), Fischenthal (Zürich), Seengen (Aargau), Walenstadt (St. Gallen), Giswil (Luzern), Wäldi (Thurgau), Engelberg (Obwalden) and Oberems (Wallis). For each municipality so-called *Zentrumszonen (center zones),* which in the

Swiss planning context typically contain the most traditional building structures were examined, resulting in a total of 17 zones (1-2 per municipality). Land cover within these zones was classified into three categories: Green spaces, buildings and sealed surfaces. The classification was manually digitized from aerial images in ArcGIS Pro. Figure 9 displays one of the land cover analyses of a center zone of Seengen.

Figure 9: Land Cover Analysis of a Center Zone in Seengen. Own map

Across the sample, the mean proportion of buildings was approximately 30%, with green spaces ranging from 35% to 40%. More urbanized rural municipalities, such as Engelberg and Walenstadt showed lower green-space proportions (10-25%), while higher amounts (~50%) were observed in smaller villages like Oberems and Wäldi.

Furthermore, the valid building ordinances, last updated between 2010 and 2025, were reviewed to gather information for parameters related to allowable floor area ratios or site coverage. However many municipalities lacked specifications. Maximum eave heights ranged from 5 m (Fischenthal) to 20 m (Engelberg), with most buildings allowed to have 2–3 stories. Minium setbacks ranged from 2.5–4 m (small) and 4–8 m (large), while allowed building lengths commonly fell between 20-40 m. Due to the variation and missing regulations, the regulatory framework across all rural municipalities appeared heterogeneous. Therefore, the focus was set primarily on realistic building heights, story numbers, roof types – predominantly pitched roofs – and native vegetation such as birch trees.

The land cover analysis and the references to the building ordinances are provided in Appendix A.

3.1.2 City Engine

An initial model of a potential center zone was created in ArcGIS CityEngine 2024.0. CityEngine is a ESRI software for 3D modeling, mainly used for procedural urban design, that allows the visualization of regulatory frameworks and land-use conditions, and further export in high-end visualization softwares and game engines (ESRI, 2025).

Firstly, the street network was created. Regarding the dimensions of the street space, the design followed the Swiss standard SN 640 201 with widths that are in line with typical dimensions observed in rural Swiss village settings and therefore provided a realistic representation of local street profiles (Schweizerischer Verband der Strassen- und Verkehrsfachleute (VSS), 2015). Following the street network, to convey a recognizable village identity, the land cover with spaces for green zones, buildings and sealed surfaces were placed, regarding the dimensions from the analysis in Section 3.1.1. The building shells were initially imported from the swissBUILDINGS3D 2.0 dataset, selecting only shapes from rural municipalities. Furthermore, key building types such as a church and a typical rural shop (Volg) were added.

However, except for background buildings, the building shells were later replaced in Unreal Engine. While CityEngine can efficiently generate urban environments via procedural modeling, it offers limited flexibility for rural settings, especially without programming knowledge. Detailed façade customization such as adding windows, doors or ornaments, typically requires scripting rules. Therefore, this step was done in Unreal Engine, where more detailed assets and texture sets are provided in the FAB Library of Unreal Engine.

Nonetheless, CityEngine was suitable for creating the broader landscape of a rural center zone including land cover classification (green zones, sealed surfaces, buildings), different parcel boundaries such as fences or hedges, street elements like vehicles, street lamps, benches and bins and places for vegetation like trees or flowers. The completed CityEngine model was exported into Unreal Engine for further refinement, as described in the following section. Figure 10 shows the CityEngine model prior to its transfer into Unreal Engine.

Figure 10: 3D Environment in CityEngine: Top-Down View (left), Backyard View (top right), Street View (lower right)

3.1.3 Unreal Engine

Unreal Engine is a powerful real-time 3D creation tool developed by Epic Games, primarily used for building games but also applied in film, architecture and simulation. It provides high-fidelity graphics and a versatile tool that enables implementation in virtual reality (Epic Games, 2025a).

The export of the environment from CityEngine and its import into Unreal Engine was carried out via the *Datasmith* pipeline. Using Unreal Engine's Dataprep import workflow, assets could be replaced with high-quality Unreal versions, which offer far greater realism and details compared to their CityEngine counterparts (Neukom & Fotheringham, 2022). A comparison between the Audi A6 asset in CityEngine and Unreal Engine is shown in Figure 11.

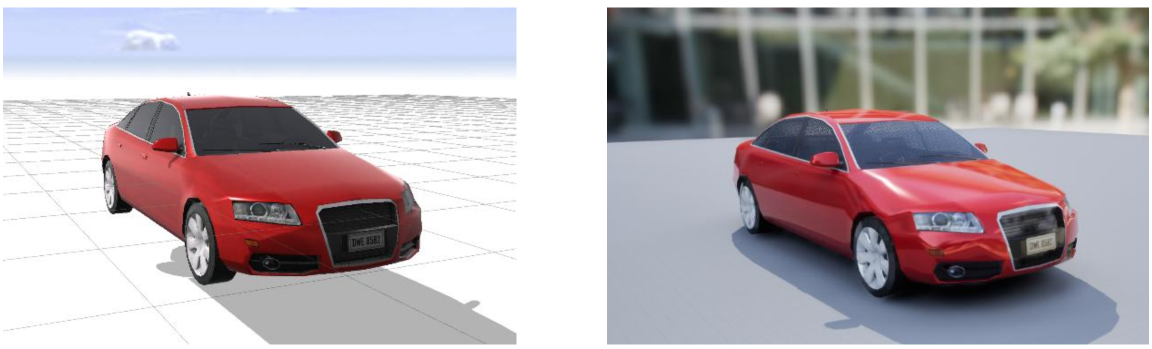

Figure 11: Comparison of the Audi A6 asset in CityEngine 2024.0 (left) vs. Unreal Engine 5.4.4 (right)

It is important to note that the VR headset used in this study supported synchronization only up to Unreal Engine version 5.4.4. A "down-integration" from newer versions (e.g. 5.5.4) was not possible. Due to this limitation, the Unreal Engine import and performing the necessary adjustment steps in this thesis had to be carried out twice.

Not all assets from CityEngine rendered correctly in Unreal Engine and had to be replaced. In some cases, positional offsets occurred (e.g. the street network and fences were no longer aligned), necessitating substantial manual adjustments. Based on this experience, it can be concluded that less preparatory detail should be done in CityEngine, as it may require reworking after import into Unreal Engine.

Two primary points of view were defined from the outset. One in a backyard and one along a street. Since participants were only intended to have a 180° horizontal field of view, grey walls were placed behind the viewpoints. For each view, detailed building models were placed in the foreground, including details on the façade like windows and doors, ornamental features and other detail that were not present in the simple swissBUILDINGS3D volumes. Roofs were textured with tile patterns. Furthermore, the church and vegetation were replaced with realistic assets, ensuring the use of vegetation species native to Switzerland. Additionally the scenes were complemented with open space elements. Textures for surfaces (e.g. green spaces, sealed surfaces) were adjusted with regard to their roughness and reflection in the material editor. Background buildings and elements like trees were added according to the viewpoint composition so that the environment conveyed the impression of a continuous village rather than an enclosed stage set.

For the stimuli, always the same buildings were used with regard to the Color–Material texture. All other buildings were left white without any assigned material texture. In the end the environment with the two location views was duplicated six times, one for each stimulus, so that each Color–Material combination could be applied while the rest of the scene remained completely identical.

The scenes of the two viewpoints with the Red–Concrete condition are displayed in Figure 12 and in Figure 13.

Figure 12: Street Scene with the Stimuli Red–Concrete in Unreal Engine

Figure 13: Backyard Scene with the Stimuli Red–Concrete in Unreal Engine

3.1.4 Virtual Reality Implementation

The environments created in Unreal Engine were subsequently integrated into the VR workflow. Lighting conditions were configured. Unreal Engine, as a highly versatile development platform for professional development, offers numerous parameters to affect scene lighting, from Sky Atmosphere to Volumetric Clouds. The parameter that was prioritized in this study was the *Directional Light* actor as it represents the position and orientation of the sun. The light source was positioned at coordinates (0.0, 0.0, 100) with a scale factor of (2.5, 2.5, 2.5). Its rotation parameters were set to a pitch of -36°, a yaw of 54°, and a roll of 0°. This configuration corresponds to a solar elevation of approximately 36° above the horizon and an azimuth indicating a position slightly south of east. Such a setting produces illumination conditions, comparable to a clear late-morning scenario, with the sun already well above the horizon yet not at its zenith and together with the *Volumetric Clouds* actor provides a balanced natural light for the virtual scenes.

For performance optimization, 3D Grass initially generated via the Foliage tool, had to be removed, as it caused performance issues. Furthermore, in the VR workflow the Self-Assessment Manikin image and the baseline video were integrated. Figure 14 and Figure 15 show the two viewpoints of Red Concrete after final implementation in Virtual Reality. Further, in Appendix E, pictures of all 12 scenes are presented.

Figure 14: Street Scene with the Stimuli Red Concrete in Virtual Reality

Figure 15: Backyard Scene with the Stimuli Red Concrete in Virtual Reality

3.2 Experimental Design

This section outlines the methodological framework used to conduct the experiment, to ensure validity, reliability of the findings and reproducibility of the experiment.

3.2.1 Study Design

The experiment employed a mixed factorial design with both within–subjects and between–subjects factors. The within–subjects factors comprised the stimulus dimensions of Color and Material while the between–subjects factor reflected each participant's residential background (see Section 3.2.2).

Each participant was exposed to all 12 experimental conditions (within-subjects), presented in a randomized order. The conditions consisted of a full factorial combination of three factors: Color (3 levels), Material (2 levels) and Location (2 levels) resulting in 3 x 2 x 2 = 12 unique stimuli.

To examine the effect of color temperature, only pure hues were used to ensure a clear distinction in chromaticity only. The specifically used sRGB values were as follows:

- Warm Color: Red (sRGB 255, 0, 0)
- Cold Color: Blue (sRGB 0, 0, 255)
- Neutral Color: White (sRGB 255, 255, 255)

Colors were applied on façade surfaces using material textures rendered in Unreal Engine. The material factor distinguished between natural and more highly processed materials:

- Natural Material: Wooden planks, using a generic wood texture from the Quixel Megascans library (FAB, Unreal Engine).
- Processed Material: Concrete façade, also from the Quixel Megascans collection (FAB, Unreal Engine)

The detailed frameworks, including the classifications of colors and materials and the choice of the representatives are displayed in Appendix C. Each color was combined with each material, resulting in six distinct Color–Material combinations (e.g. Blue–Wood, Red–Concrete). A detailed overview of the visual representation of the Color–Material combination workflow can be found in Appendix D.

To control for related spatial-layout confounds, two distinct rural scene types with the viewpoints (see Section 3.1.3 and 3.1.4) – namely, a Street scene and a Backyard scene – were included. This design choice aimed to prevent potential biases arising from specific spatial arrangements – for example, building orientation – within a single scenario, while maintaining a consistent environmental context.

3.2.2 Participants

A total of 39 participants took part in the experiment. The gender distribution was uneven, with 25 women (64.1%) and 14 men (35.9%) participating. Consequently, any potential bias resulting from this imbalance was considered in the analysis. According to an a priori power analysis conducted with G*Power (see Figure 16) the minimum required sample size to detect the interaction of Color x Material in a repeated measures ANOVA (within-between interaction) is 36 participants, assuming a medium effect size (f = 0.25), an α-error probability of 0.05, three groups (City, Agglomeration, Countryside) and six measurements (3 Colors x 2 Materials). Thus, the needed size of the study group for testing the significance was fulfilled. Moreover, with 39 participants the study group was in line with other studies or even higher (see Section 2.3.2).

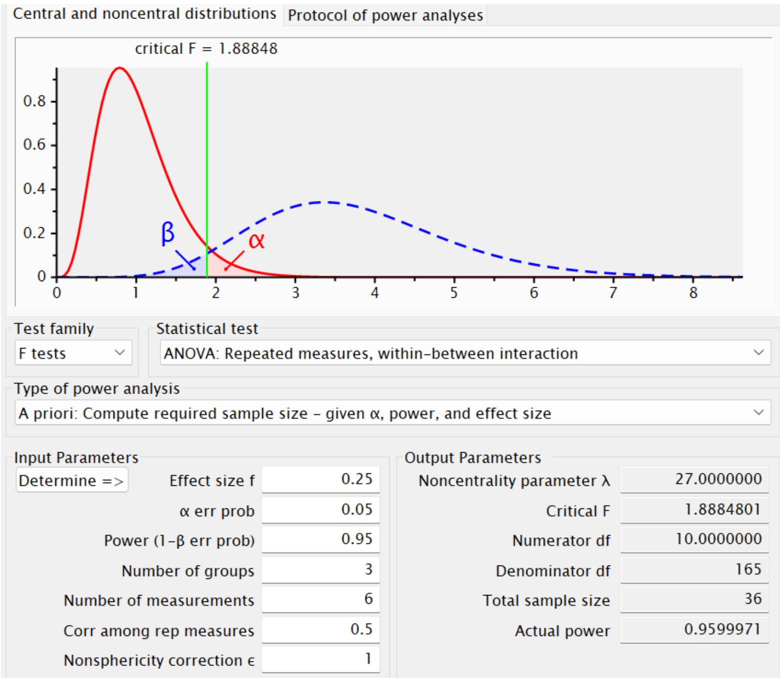

*Figure 16: G*Power calculation for Sample Size*

The age of the participants ranged between 21 and 29 years. For the analysis of **RQ3**, all participants needed to meet the inclusion criteria of either holding Swiss citizenship or having grown up in Switzerland. Thus, potential cross-national cultural biases regarding color perception as for instance Madden et al. (2000) mentioned were excluded.

Furthermore, participants were categorized based on their residential background as urban (*City*), suburban (*Agglomeration*) and rural (*Countryside*). The self-reported distribution of participants upbringing was relatively balanced: 16 participants (41.03%) reported having grown up in a rural area, 12 (30.77%) in an agglomeration and 11 (28.21%) in an urban area. However, the distribution of current place of residence showed a strong shift towards urban areas, with 33 participants currently living in a city, 2 in an agglomeration and 4 in rural areas. Furthermore, the participants were asked to place their current municipality of residence on a map. According to the typology of the FSO, 35 participants were currently living in a city, 2 in an agglomeration and 2 in rural areas.

3.2.3 Devices

The VR environments were rendered via SteamVR and displayed through the *HTC VIVE Pro Eye* head-mounted display (HMD). The HMD features dual OLED screens (3.5. inches each) with a resolution of 1440 x 1600 pixels per eye, resulting in a combined resolution of 2880 x 1600 pixels. The refresh rate is 90 Hz, and the field of view is 110 degrees, providing solid technical specifications for a VR study. Additionally, the headset offers integrated audio playback and can be paired with hand controllers (HTC, 2025). However, both functions were intentionally disabled in this study to ensure that the experimental focus remained solely on the visual dimension. The HTC VIVE Pro Eye has been employed in various scientific studies involving emotion recognition in VR, for example by Mousavi et al. (2023) and Mancuso et al. (2024) and is considered an appropriate device for the purposes of this study.

Electrodermal activity (EDA) was recorded using the low-cost biosignal acquistion kit *BITalino PsychoBIT* in combination with the OpenSignals (r)evolution software. The system is designed for basic psychophysiological data acquisition, including heart rate, blood pressure, respiration and skin conductance (PLUX Biosignals, 2025). The device is portable, light-weight and battery-powered. Thus, it can be used versatilely in mobile, lab or field setups without being tied to a fixed station. Data is transmitted via Bluetooth to the computer running OpenSignals software (Batista et al., 2019).

A benchmarking study by Batista et al. (2019), which compared the BITalino platform with the BioPac system, the gold standard in many laboratories costing several thousand euros and featuring clinical-grade certification, found comparable signal quality. This indicates that the more affordable BITalino device is particularly well suited for exploratory research in non-clinical laboratory setups, like the present study.

3.2.4 Study Procedure

The study took place in the CAVE Lab at the Department of Geography, University of Zurich, located on the Irchel Campus. Participants were recruited through personal communication, including word of mouth and private messaging platforms (e.g. WhatsApp, email). The experiment could be conducted in either English or German, dependent on the participant's preference. Before each experimental session, several preparatory steps were taken. First, the workspace, the head-mounted display (HMD) and the BITalino device were cleaned with alcohol to ensure proper disinfection. Next, the HMD headset was connected and tested, which included plugging in the tracking sensors and launching the SteamVR software. BITalino was also connected and the data acquisition and trigger impulse functionality were tested using the OpenSignals (r)evolution software. In order to determine the presentation order of the 12 virtual scenarios for each participant, a randomized sequence was generated using the Random Sequence Generator (*RANDOM.ORG - Sequence Generator*, 2025).

The experiment was divided into three parts. First, participants were given time to read and sign the informed consent form and additional instructions regarding the overall procedure of the study, as well as key information about their tasks during the virtual reality experience and the use of the HMD and BITalino. Important information included the potential risks of experiencing headaches or discomfort in virtual reality. In such cases, participants were advised too close their eyes and remove the headset. In general the experiment could be terminated at any time without consequence. Participants were encouraged to immediately report any discomfort. No participants withdrew from the study, and no significant adverse effects were reported.

After the instruction, participants were asked to take a seat. Electrodes for the EDA recording were then attached to the palm of their right hand. The red electrode was placed on the middle finger, and the black electrode on the index finger, positioned at the middle joint. At the beginning of the baseline video, participants were instructed to rest their hand calmly on their leg to minimize movement artifacts in the data. As the participants remained seated and did not move their hands during the virtual reality experience, the electrodermal activity on the right hand for everyone, regardless of dominance. As a result, three participants did the experiment on their non-dominant hand. Figure 17 displays how the participants stayed during the virtual reality task and how the Bitalino device was fixed on the hand.

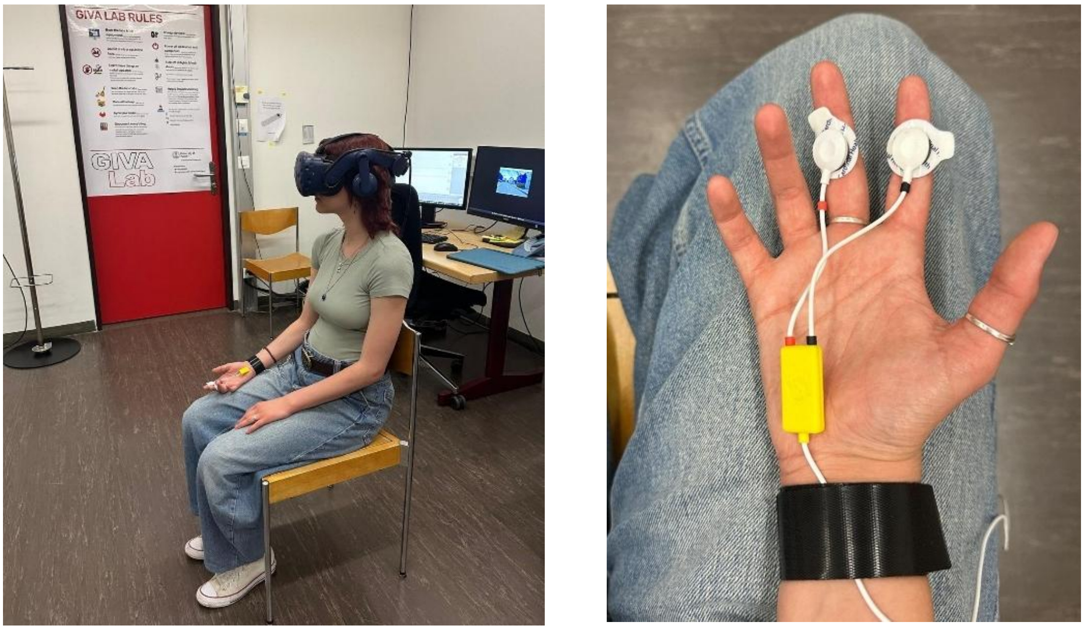

Figure 17: Participant during the VR-experiment in the CAVE Lab (left), placement of Bitalino device on the fingers (right). Own photographs

The second phase of the experiment involved the virtual reality experience. It began with a video presentation of a waterfall used to measure the physiological baseline. After the baseline video, the 12 experimental situations were presented. A timeline of the VR procedure, including the experimenter's tasks, is provided in Appendix G.

The 12 virtual situations, the baseline video, and the SAM image were each assigned to predefined keyboard keys. In detail, the 'V'-key was used to start the baseline video, the 'P'-key triggered the SAM image and the scenarios were activated using the number keys from 1 to 0 and the 1 and 2 keys on the numeric keypad. Switching between the different scenarios was performed manually by pressing the corresponding key. In addition, to match post-hoc the physiological data to the corresponding virtual scenarios, a separate trigger was manually pressed via the BITalino device at the beginning of each scenario. This was done independently of the keyboard input.

The duration of the baseline video was automatically fixed at 3 minutes, while the SAM image after each situation was displayed for 30 seconds. The 12 virtual scenarios also lasted 30 seconds each, with timing controlled manually. During the experiment, the experimenter guided participants by announcing the upcoming scenario approximately five seconds before each transition.

Finally, after the virtual reality experience, the participants were asked to complete a survey, created with ArcGIS Survey123. The survey included questions related to the presented scenarios, participants' personal residential background in Switzerland – such as their place of residence or where they grew up – and socio-demographic questions. The English version of the full survey, translated automatically from ArcGIS is available in Appendix H. Upon completion, the participants received a small gift as a sign of appreciation. The total duration of the experiment lasted approximately 30 to 45 minutes, depending on individual pacing. All procedures were carried out in accordance with ethical guidelines.

3.3 Data Processing and Analysis

The collected data were subsequently processed and analyzed. All statistical analyses were performed using Python. The choice followed the guidelines proposed by Field et al. (2012).

3.3.1 Electrodermal Activity Data

Data Processing

Electrodermal activity were acquired using the BITalino device via the A4 input and transmitted via Bluetooth to the computer running OpenSignals (r)evolution software, which is recommended for use by the Bitalino provider (PLUX Biosignals, 2025). Electrode placement on the hand is described in detail in Section 3.2.3, along with Figure 17. Data were saved in EDF, TXT and H5 formats in continuous mode with converted values at a sampling frequency of 100 Hz. For the analysis of this study, the converted TXT files were used, as they contained EDA values already converted and expressed in micro Siemens (μS).

From each TXT file, only the data of interest wre extracted. Specifically, the baseline period (180 s prior to the trigger, marking the first experimental situation) and the twelve stimulus situations (defined between successive trigger clicks) were retained. Triggers were recorded via the I2 digital input. Intervals containing the SAM images, which were displayed between situations for 30 s each, were excluded. In cases where two trigger clicks occurred within less than 3 s due to experimental error, the earlier of the two was discarded and the latter retained. The resulting baseline and situation segments were stored as single Excel files for each participant.

Signal processing and analysis followed the methodological principles of Lanini-Maggi (2023), with using the tool *NeuroKit2* in Python. In a first step, EDA signals were preprocessed by applying a five-point moving-average filter iteratively five time to attenuate high-frequency noise; any NaN values introduced at the edges by the rolling window were replaced via backward- and forward-fill interpolation.

The smoothed signal was subsequently processed with *nk.eda_process()* which is a high-level wrapper that cleans the raw EDA signal, decomposes it into tonic and phasic components and detects skin conductance responses (SCRs). Internally, it filters and standardizes the signal by applying a Biopac–style method (cutoff ≈ 0.05 Hz) to separate the components. Finally, it detects SCR onsets and peaks, computing amplitudes using a default threshold of 0.1 µS, and outputs both a feature dictionary and a time-aligned signals DataFrame (Makowski et al., 2021). To normalize the phasic activity, the phasic component was scaled to the percentage of its full amplitude range, after which negative values were set to zero so that only positive phasic peaks were retained (PHI_pos) (Lanini-Maggi, 2023).

Segments were defined by identifying the baseline interval and for each stimulus an analysis window beginning 1 s after stimulus onset and ending 4 s post-onset. This time window was chosen to avoid potential artefacts from scene switching or trigger execution, account for the typical physiological latency of SCRs (1-3s post-stimulus) and capture the main peak period of the SCR while avoiding overlap with potential subsequent stimuli (Figner & Murphy, 2011). For the calculation of the baseline rate, the full 180 s baseline was used excluding the first 10s as warm up period for the baseline rate.

For each stimulus, following EDA metrics were calculated, with standardized Deltas according to Spielhofer et al. (2021):

- ***AUC rate:*** *Area Under the positive phasic Curve per second (AUC /s), with Delta rate = AUC rate – baseline AUC rate*
- ***nSCR:*** *Number of SCR onsets within the segment window*
- ***Tonic mean****: Average tonic level, with Delta tonic = Tonic mean – Tonic baseline*

Figure 18 shows the baseline corrected phasic EDA from Participant 1 over the 12 situations.

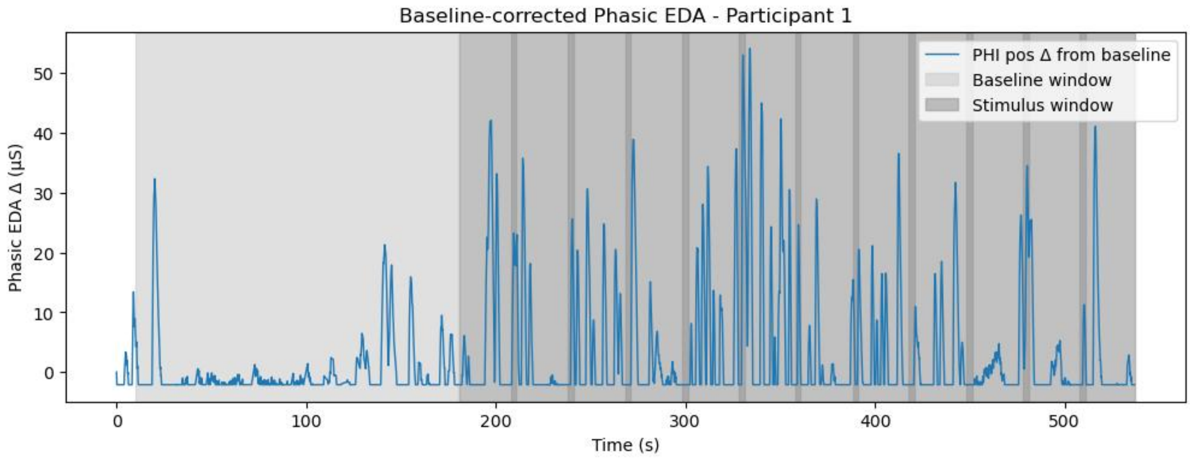

Figure 18: Processed Electrodermal Activity (EDA) Signals of Participant 1

Data Analysis

The QQ-Plots for all EDA metrics, including AUC rate, Delta rate, nSCR, Tonic mean and Delta tonic deviate substantially from the theoretical normal line (see Appendix I), leading to the rejection of the normality assumption. Consequently, non-parametric and rank-based methods were employed throughout. Initially, descriptive statistics such as median (Md) and standard deviation (SD) were calculated with boxplots to visualize the distribution of the stimuli.

On AUC rate, tonic mean and nSCR an Aligned–Rank–Transform (ART) ANOVA was conducted to test for main effects of Color (Blue, Red, White) and Material (Concrete, Wood). Delta rate and AUC rate, as well as tonic mean and Delta tonic, yielded identical ANOVA outcomes and are therefore not reported separately. Post-hoc analyses applied a Friedman test for Color and paired Wilcoxon signed–rank test for Material with Bonferroni–correction for multiple comparisons. For any significant three-way Color x Material x Location interaction, rank transformations followed by Bonferroni–corrected pairwise comparisons clarified the underlying pattern.

In addition a multinomial logistic (MN-Logit) Regression was performed to predict stimulus categories (Color or Material) from EDA metrics, using the formula:

Stimuli (Color/Material) ~ AUC Rate / Tonic Mean + nSCR

Gender and Residential Background (Agglomeration, City, Countryside) were assessed only for metric showing significant main effects (nSCR) via Mann–Whitney U tests for Gender and

Kruskal–Wallis tests followed by Dunn's post-hoc tests with Bonferroni–correction for Residential Background. Significant results were further validated through a rank-based mixed–effects model of the form:

*EDA metric ~ C(Residential Background) * C(Color) * C(Material) + (1 | Subject)*

Effect sizes were calculated using Cohen's *d*, with interpretation according to Cohen (1988) as shown in

Table 1.

Cohen's *d* range	**Effect size**
< 0.20	Negligible
0.20 - < 0.50	Small
0.50 - < 0.80	Medium
≥ 0.80	Large

Table 1: Cohen's d effect sizes (Cohen, 1988)

3.3.2 Subjective Measurements

Processing

After each situation, participants completed the Self-Assessment Manikin (SAM) directly in the VR experience for self-report measurement as displayed in Figure 19. The SAM was presented bilingually in English and German. However a minor error occurred in which the German and English labels for "Excited" / "Aufgeregt" were swapped. None of the participants appeared to be affected by this. The SAM ratings were provided on a 1-5 scale. The upper row representing the arousal dimension from Calm (1) through Neutral (3) to Excited (5) and the lower row representing the valence dimension from Unhappy (1) through Neutral (3) to Happy (5). Participants submitted their ratings immediately after each exposure to ensure real-time responses.

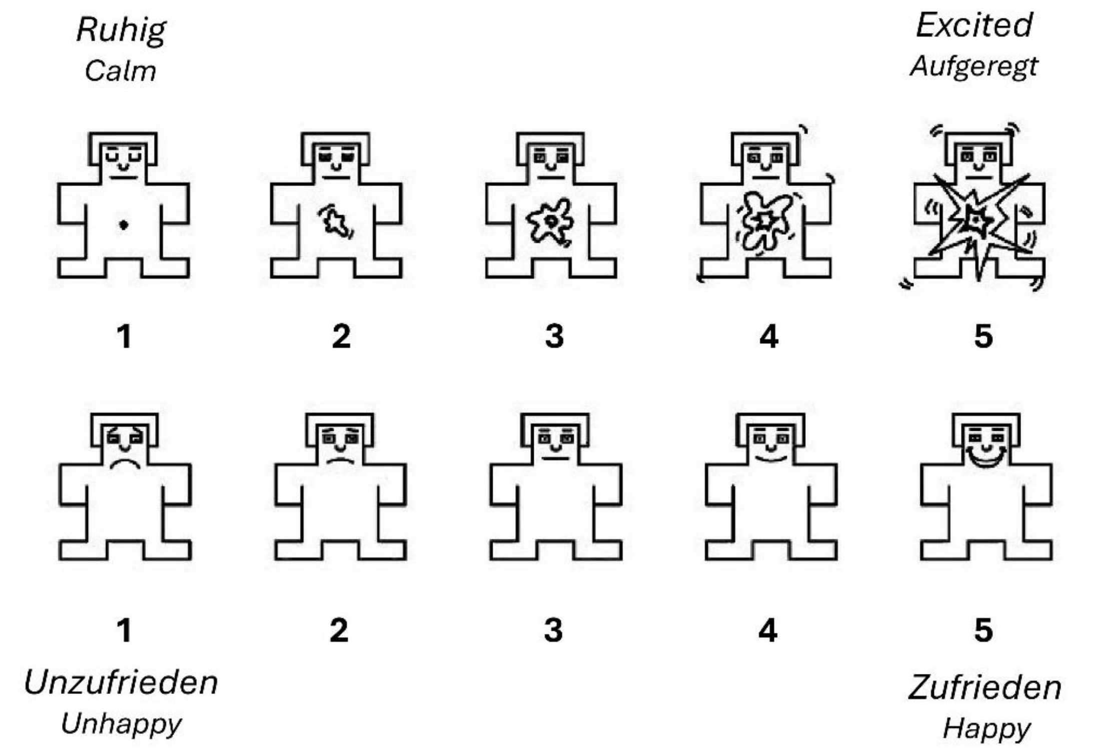

Figure 19: Self–Assessment Manikin (SAM) Picture used in the VR Experiment based on Bradley & Lang (1994)

The post-experiment questionnaire was created with ArcGIS Survey123 in both English and German. It was divided into three sections. The first section assessed participants' overall perception of colors and materials across all situations, using a Likert scale similar to SAM. Arousal from 1 (very calming) to 5 (very exciting) with 3 being to neutral baseline and valence from 1 (very unpleasant) to 5 (very pleasant). Unlike the SAM, the questionnaire explicitly stated the Stimuli for Color and Material to obtain specific ratings for validation purposes. Additional validation questions addressed stimulus combinations with an open question about whether a specific scene triggered any particular reactions. The second section gathered information on personal background and spatial imprint, including self-perception of upbringing and place of residence (City, Agglomeration, Countryside) and a map placement to provide contextualization. The final section collected demographic information such as age and gender.

Data Analysis

Data analysis for SAM and questionnaire responses followed a similar procedure to that for the EDA metrics. Descriptive statistics, including median and standard deviation were computed and boxplots were computed for visualization. Effect sizes were again quantified using Cohen's *d*.

With 39 participants completing the experiment, 468 observations per SAM dimension were obtained. The QQ-plots of the residuals, as displayed in Figure 20, indicated that the data points lie closely along the theoretical normal line, confirming the assumption of normality.

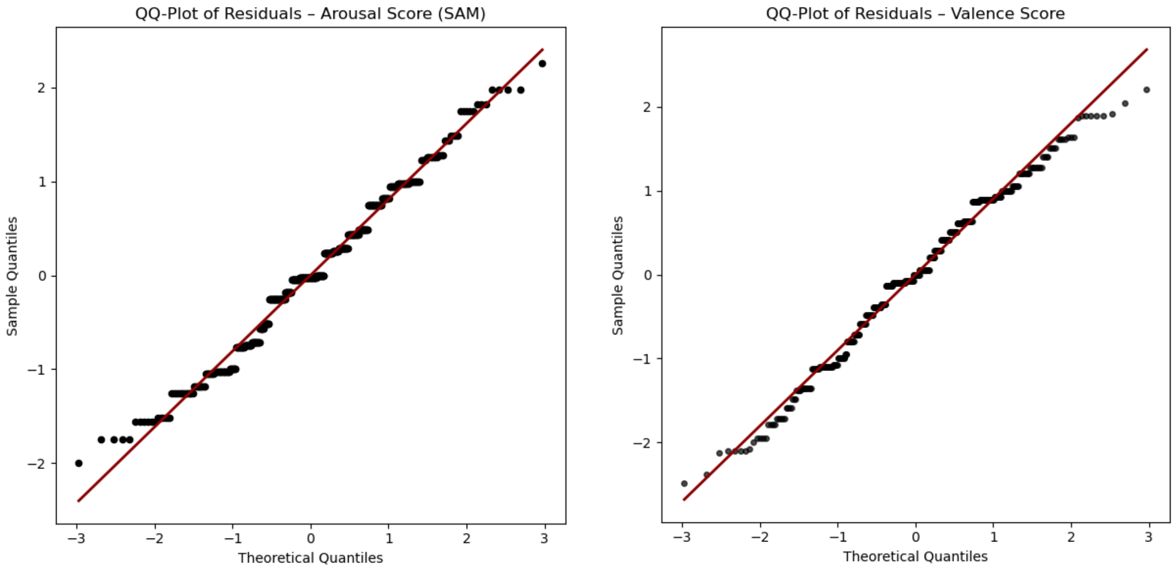

Figure 20: QQ-Plots of SAM–Arousal and Valence to test Normality

First, one-sided t–tests were performed to assess deviations from the neutral baseline (3 = neutral) toward either excitement or calmness for arousal and toward happiness or unhappiness for valence. Subsequently, the data were analyzed using three-factor Type II ANOVA, with Turkey's HSD for post hoc comparisons. Additionally, further Material x Color interaction were examined with paired t–tests. Given the imbalance of gender distribution in the dataset, eventual bias were tested using Welch t–test. To examine the influence of participants' Residential Background (City vs. Agglomeration vs. Countryside) an additive mixed–effects model was specified for overall arousal, and a linear mixed-effects model for interaction effects with random intercepts for each subject and fixed effects for Residential Background, Color and Material, including all two-and three way interactions:

$$measure \sim C(Residential\ Background) * C(Color) * C(Material) + (1 \mid Subject)$$

Significant model effects were further examined using post-hoc Welch's t–tests.

In contrast, the questionnaire data were not normally distributed (Shapiro–Wilk $p < .05$). Consequently, significance testing against the neutral baseline (3) employed one-sided Wilcoxon signed-rank tests. For the effect of Color Stimuli on arousal and valence (Red vs. Blue vs.

White) Friedman–tests were conducted, followed by Bonferroni–corrected Wilcoxon tests for pairwise comparisons. Material effects (Wood vs. Concrete) were tested with Wilcoxon signed-rank tests. Potential gender biases were assessed with Mann–Whitney U tests. Residential Background effects, based on the classification of the participant's upbringing environment into Countryside, Agglomeration or City, were evaluated with Kruskal–Wallis tests, followed by post-hoc Bonferroni–corrected Mann–Whitney U comparisons.

4. Results

In this chapter, the results regarding the research questions and hypotheses for the measured data of EDA, SAM and Questionnaire are presented. The factor levels are capitalized when referring to experimental conditions (e.g. Color: Red/Blue/White; Material: Wood/Concrete). The complete output tables of all tests which were obtained are provided in Appendix I.

4.1 Electrodermal Activity Data

Following the results of nSCR and AUC rate – representing arousal across the 12 experimental situations – are shown. Tonic mean did not exhibit any significant effects with ART ANOVA and is therefore not further analyzed. Potential effects of Gender and Residential Background are presented as well.

4.1.1 nSCR

Across the 12 experimental situations (see Figure 21), median (Md) nSCR values of 3 were observed in three Red and three Blue situations, whereas three White situations had lower medians with a minimum for White–Wood–Backyard (Md = 1.5) condition.

Aggregated by Color, median nSCR was 3.0 for Blue and Red and 2.0 for White, while aggregated by Material, medians were 3.0 for Concrete and 2.0 for Wood. Standard deviations (SD) were lowest for White (SD = 1.43), intermediate for Red (SD = 1.71), and highest for Blue (SD = 1.99), with similar variance for Concrete (SD = 1.77) and Wood (SD = 1.72). Figure 22 and Figure 23 display the boxplots by Color and by Material.

ART ANOVA confirmed significant main effects of Color with $F(2,74) = 5.29$, $p = .007$ and Material with $F(1,37) = 12.23$, $p = .001$. No significant effect was reported for the Color x Material interaction ($p = .913$), but the three-way Color x Material x Location interaction confirmed significance ($F(2, 74) = 8.56$, $p < .001$).

Post-hoc Wilcoxon tests (Bonferroni–corrected) for Color yielded significance for Blue vs White ($W = 124.5$, $p_{(corr)} < .01$, $d = 0.55$) and Red vs. White ($W = 92.0$, $p_{(corr)} < .001$, $d = 0.59$) with Red and Blue indicating higher nSCRs than White, while Blue vs. Red yielded no significance ($p_{(corr)} > .90$, $d = 0.12$). On Material, Concrete vs. Wood was significant with Concrete having more nSCR peaks than Wood ($W = 92.0$, $p < .001$, $d = 0.59$).

Three-way interaction pairwise tests showed significant differences only when comparing Blue or Red with White in Concrete–Street and Wood–Backyard contexts. (Concrete x Street x Blue vs. White: $p < .01$, Concrete x Street x Red vs. White: $p = 0.014$, Wood x Backyard x Blue vs. White: $p < 0.01$, Wood x Backyard x Red vs White: $p < 0.01$).

Testing for potential gender bias, Mann–Whitney U revealed no significant differences between Females and Males ($U = 146.5$, $p = .525$, $|d| = 0.23$).

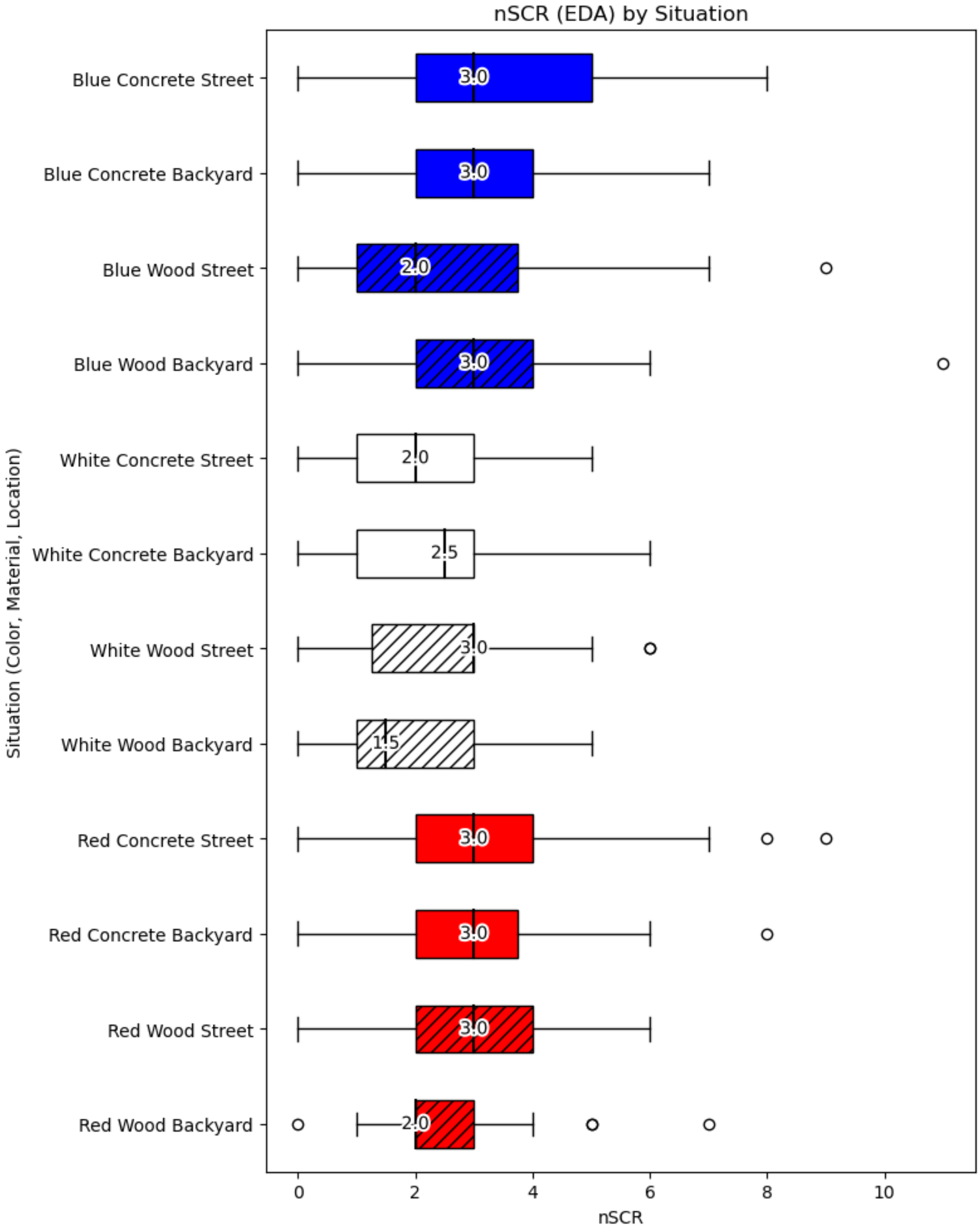

Figure 21: Boxplots of nSCR for the 12 experimental situations

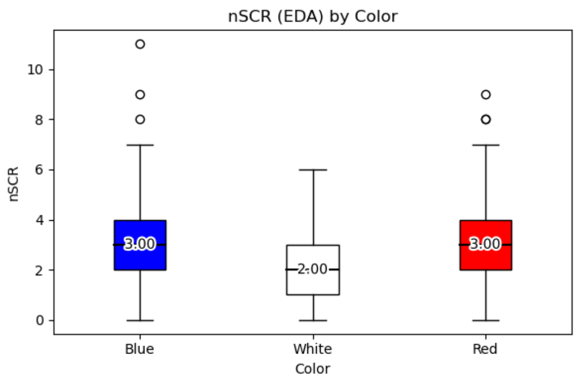

Figure 22: Boxplots of nSCR by Color

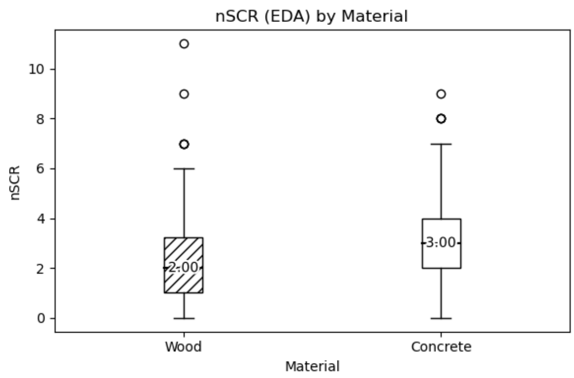

Figure 23: Boxplots of nSCR by Material

4.1.2 AUC rate

AUC rate medians varied among the 12 situations from 2.5 (White–Wood Backyard) to 4.28 (Blue–Wood Backyard). Figure 24 displays the boxplots of all situations.

Aggregated medians by Color and Material (see Figure 25 and Figure 26) were similar between the stimuli (Blue–Md. = 3.64, Red–Md. = 3.76, White–Md. = 3.81; Wood–Md. = 3.56, Concrete–Md. = 3.79).

ART ANOVA on AUC rate revealed no significant main effect for Color either ($F(2, 74) = 0.062$, $p = .940$), nor Material ($F(1, 37) = 1.576$, $p = .217$). Between the interactions only the three-way interaction Color x Material x Location yielded a modest significance with $F(2, 74) = 3.515$, $p < .05$) but post hoc Bonferroni–corrected rank tests yielded no significant pairwise contrast for the three-way interaction with effect sizes ranging from small to negligible. A rank-based mixed-effects model detected a single significant interaction for White x Wood with $\beta = -44.63$, $p = .041$, indicating lower ranked AUC for that specific combination.

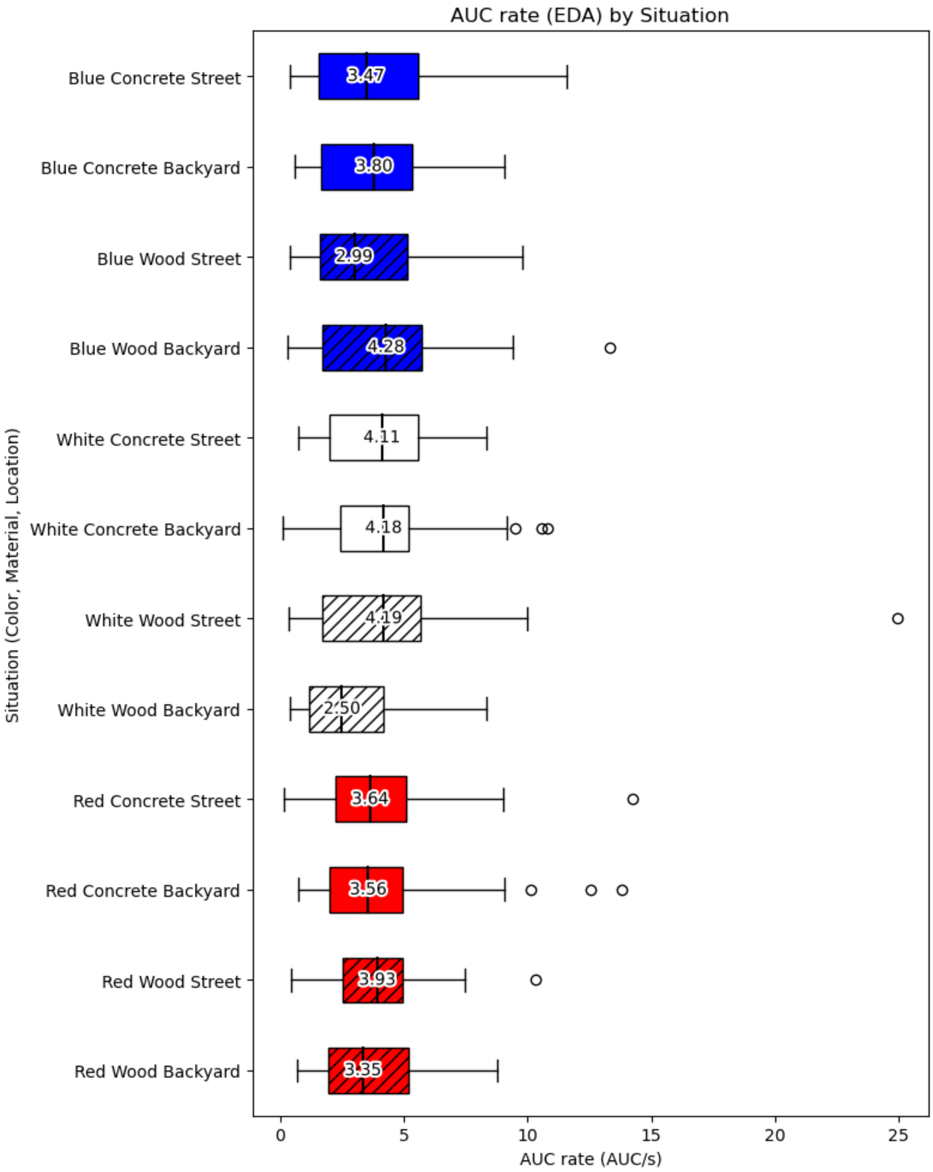

Figure 24: Boxplots of AUC rate for the 12 experimental situations

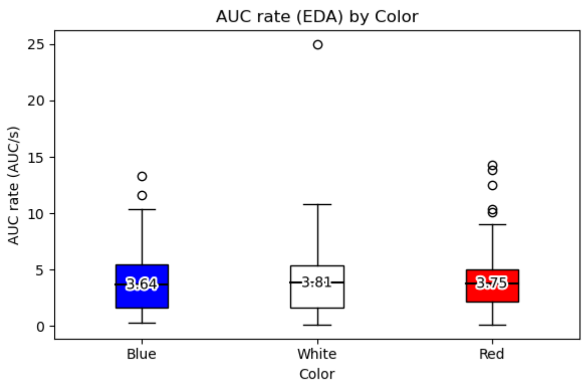

Figure 25: Boxplots of AUC rate by Color

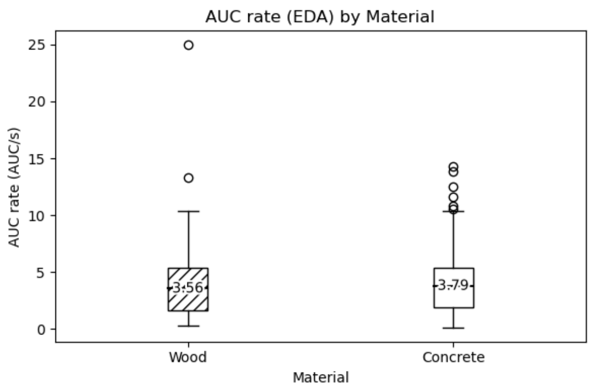

Figure 26: Boxplots of nSCRs by Material

4.1.3 Interaction AUC rate and nSCR

The MN–Logit Regression (baseline: White–Concrete) confirmed the nSCR to be the primary predictor for Color and Material with a positive association with Blue ($\beta = +0.435$, $p < .001$) and Red ($\beta = +0.351$, $p < .001$) versus White. AUC rate was also significant, but inversely predicting lower values for Blue ($\beta = -0.172$, $p < .01$) and Red ($\beta = -0.123$, $p < .01$) lower versus White. For Material nSCR predicted more peaks for Concrete over Wood ($\beta = -0.123$, $p < 0.01$) with AUC rate remaining non-significant.

4.1.4 Residential Background effects

For the Residential Background of the participants, only nSCR was analyzed as the primary EDA metric. Kruskal–Wallis revealed a significant difference in nSCR peak across the three groups (City, Agglomeration, Countryside) with $H = 6.200$, $p = .045$.

Post-hoc Dunn tests with Bonferroni–correction revealed significant effects between City and Countryside with $p_{(corr)} = .040$, $d = 1.06$ with the City group exhibiting a higher peak count. The comparisons City vs. Agglomeration ($p_{(corr)} = .309$, $d = 0.78$) and Agglomeration vs. Countryside ($p_{(corr)} = 1.000$, $d = 0.43$) were not significant, although medium to large effect sizes suggest that arousal decreased as the background became more rural.

A rank-based mixed-effects model examining the interactions Residential Background x Color, Residential Background x Material and the three-way interaction Residential Background x Color x Material revealed no significant effects. This indicates that the elevated arousal in the City group cannot be attributed to any specific Color, Material or their combination.

4.2 Self-Assessment Manikin Data

The Self-Assessment data was measured on a Likert Scale for 1-5, with 1 = Calm, 3 = Neutral and 5 = Excited.

4.2.1 Arousal

Across all twelve scenarios, Red conditions – regardless of Material or Location – yielded the highest median arousal rating ($Md = 3.0$) whereas both Blue and White conditions recorded a median of 2.0, indicating that Red scenes were perceived as most arousing and Blue and White scenes similarly calm. Variability among the Color x Material situations was relatively similar, with standard deviation SD range from 0.66-0.92, with higher variability for the Red and Blue scenarios and lower variability for the White scenarios, independent of its material.

Regarding Material, the boxplots (Figure 27) revealed no substantial differences between Concrete and Wood surfaces. However, one-sided t–tests against the baseline of a neutral arousal (= 3) showed all Colors and Materials lying significantly below the baseline (all $t < -4.00$, all $p < 0.0005$). This indicates that in general Color Stimuli have no strong excitement effect and Materials a calming effect. The three-factor Type II ANOVA confirmed a highly significant, large main effect of different Colors on arousal with $F(2, 456) = 39.60$, $p < .001$). Post hoc Tukey HSD tests showed that the Red scenes evoked significantly higher arousal with a medium-large increase relative to Blue (mean difference = +0.526, $p < .001$, Cohen's $d = 0.59$), a large increase relative to White (+0.814, $p < .001$, $d = 1.03$) and that Blue itself produced a small-medium increase over White (+0.289, $p = .006$, $d = 0.37$). This results in a significant ranking of Red > Blue > White in terms of subjective arousal. Detailed Tukey HSD results for all twelve stimuli and their significance levels are provided in Appendix I.

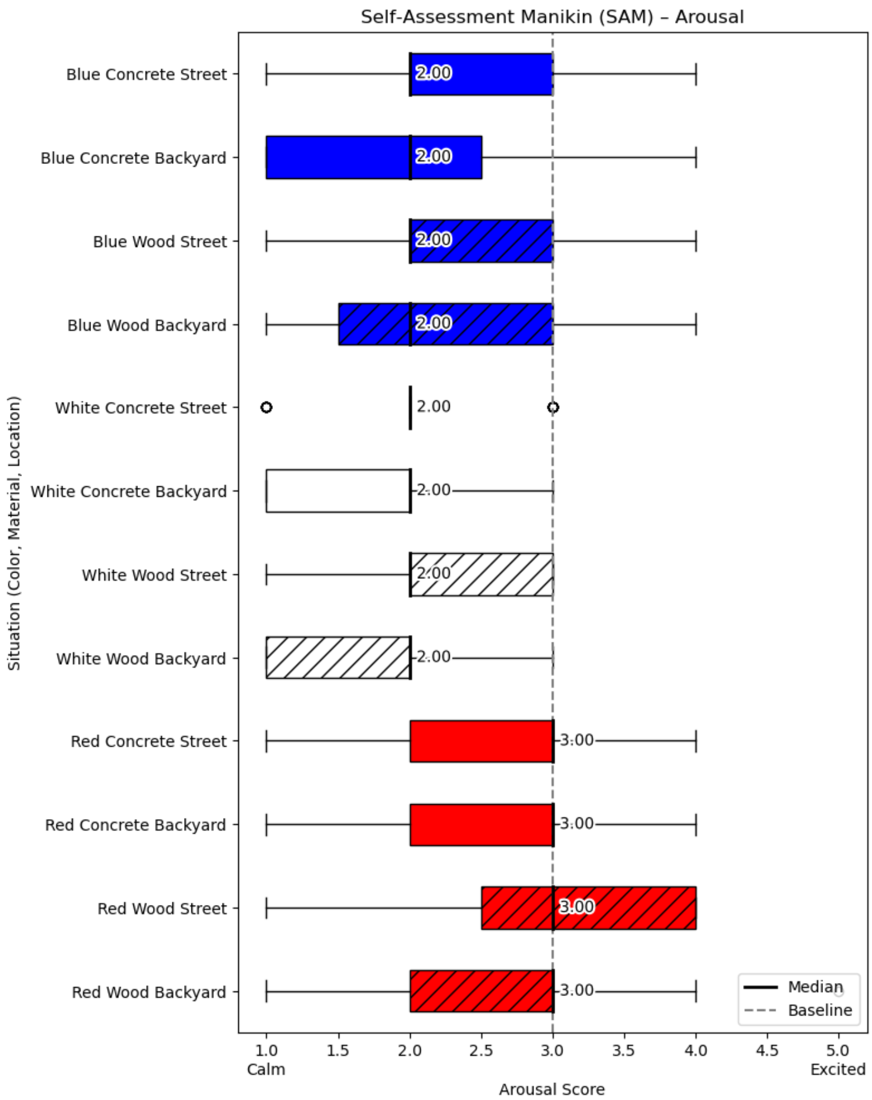

Figure 27: Boxplots of Arousal-SAM of the 12 experimental situations

The two-way interactions of Color x Material (F, (2, 456) = 1.88, p = .155), Color x Location (F(2, 456) = 0.39, p = .681) and Material x Location (F(1, 456) = 0.07, p = .778), as well as the three-way interaction Color x Material x Location (F(2, 456) = 0.48, p = .619) were all non-significant. This indicates that the effect of color on arousal does not depend on surface type or setting. Indeed, the interaction plot between Color x Material (see Figure 28) shows that mean arousal for Blue–Wood versus Blue–Concrete and White–Wood versus White Concrete are relatively identical. In contrast Red (Mean M = 2.87) elicited higher arousal than Red–Concrete (M = 2.54). A paired t–test within the Red condition uncovered this Material effect with Red–Wood producing a significantly higher arousal than Red–Concrete (p <.001, d = -0.703), suggesting a modest Material influence.

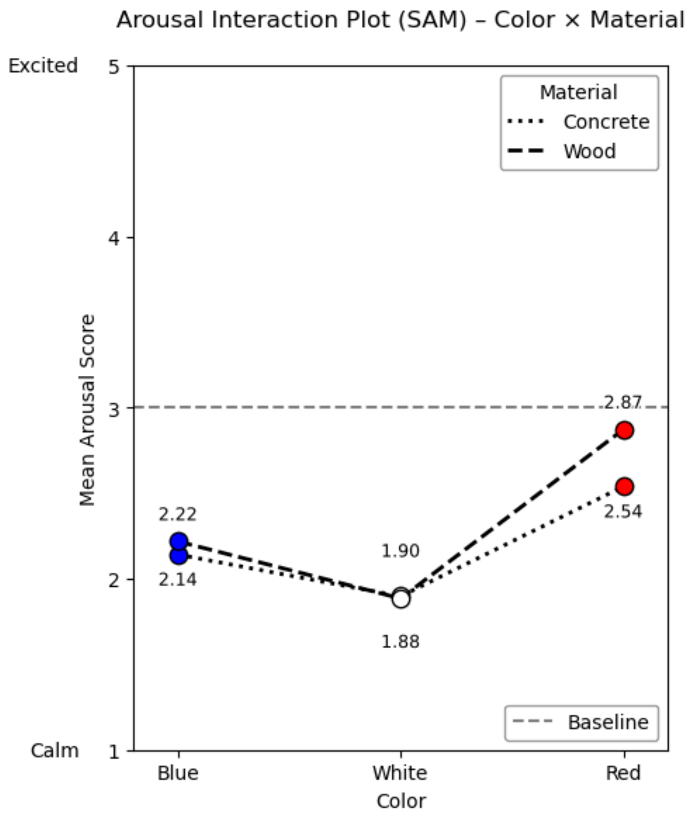

Figure 28: SAM–Arousal Interaction Plot Color x Material

The Welch t–tests comparing women and men revealed no gender biases in arousal for either Color or Material. There are no significant differences for Blue (t = 0.784, p = .435), Red (t = 0.809, p = .420) and White (t = -0.468, p = .640) and likewise no differences for Concrete (t = 0.225, p = 0.822) and Wood (t= -0.315, p = 0.753).

4.2.2 Valence

The Self-Assessment data was measured on a Likert Scale from 1-5, with 1 = Unhappy, 3 = Neutral and 5 = Happy. Visually as shown in Figure 29, Valence ratings are broadly comparable across all twelve scenarios. Red scenes tend to have the lowest ratings and White and Blue stimuli were slightly higher. The variability is similar across the situations with SD values ranging between ≈ 0.84-1.03, noticeably greater than for arousal. No systematic differences between Concrete and Wood surfaces are apparent. One sided t–tests showed that the Color Stimuli of Blue ($t = 3.391$, $p < 0.001$) and White ($t = 4.500$, $p = .00001$), lay significantly above the baseline, which indicates that these Color Stimuli induce happiness. Red on the other hand did not significant differ from the baseline ($t = 1.207$, $p > .10$), which indicates that Red neither induce happiness nor unhappiness. Both materials, Concrete ($t = 4.423$, $p = .00001$) and Wood ($t = 2.852$, $p < 0.005$) were also significantly above the baseline level, indicating general no reduction in valence for Material.

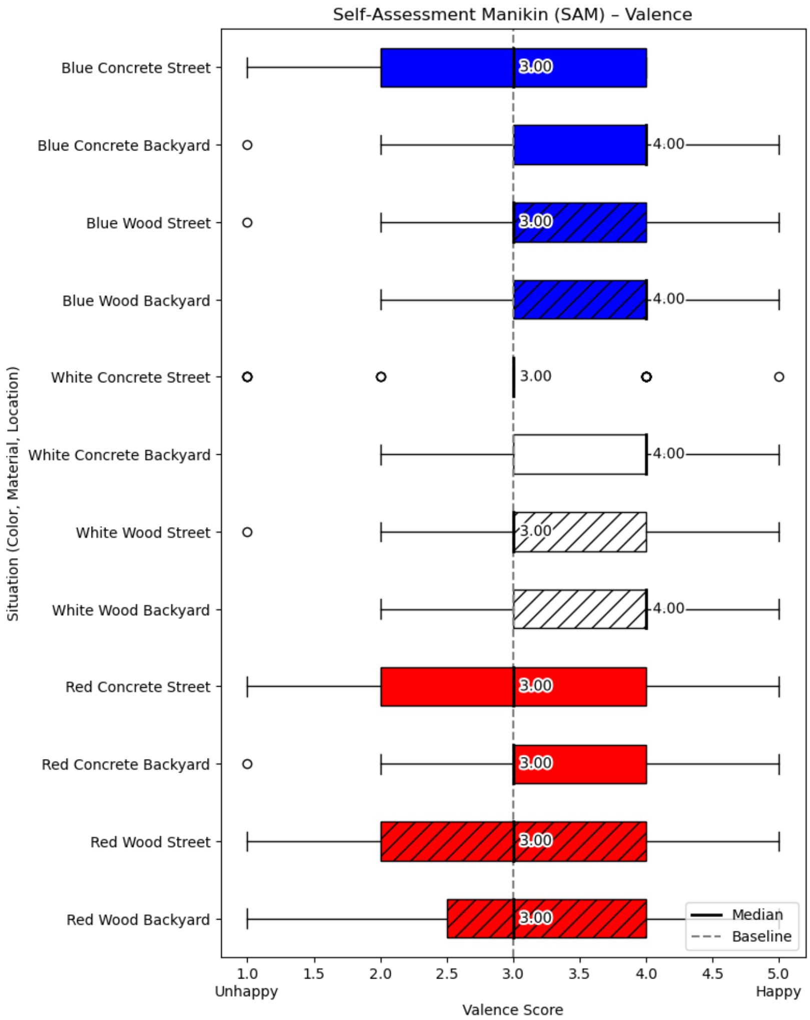

Figure 29: Boxplots of Valence-SAM of the 12 experimental situations

The three-factor Type-II ANOVA supports the visual results. The effect of Color on valence was not statistically significant at $\alpha = .05$, although it approached trend-level ($F(2, 456) = 2.67$, $p \approx .070$, $\eta^2 \approx 0.011$). Thus, the pairwise effect size between the Colors were all small: Blue vs Red: Cohen's $d = 0.156$, Blue vs White: d = -0.098, Red vs White: $d = -0.247$.

Material showed no significant effect F(1, 456) = 1.35, p = .245), therefore no significance between Concrete and Wood scenes was observed ($d = 0.104$). In contrast, Location yielded a robust main effect. Backyard scenes were rated more positively than street scenes, with F(1, 456), = 26.03, p < .001, corresponding to medium effect size ($d = 0.47$). All two– and three–way interactions were non-significant (all p > .20), indicating independence of these factors.

Although the overall Color x Material interaction did not reach statistical significance in the ANOVA (F(2, 456, p = .26), an in-depth comparison within each Color revealed a pronounced Material effect for the red scenes similar to the arousal dimension. As shown in Figure 30, Red–Concrete Stimuli elicited higher valence (M = 3.24) than Red–Wood stimuli, which fell below baseline level (M = 2.95). This indicates that in combination with Wood, Red doesn't induce happiness. A paired t–test for the stimuli Red x Material yielded a moderately significant effect with t = 5.675, p < .001 and a medium-to-large Cohen's d of 0.643.

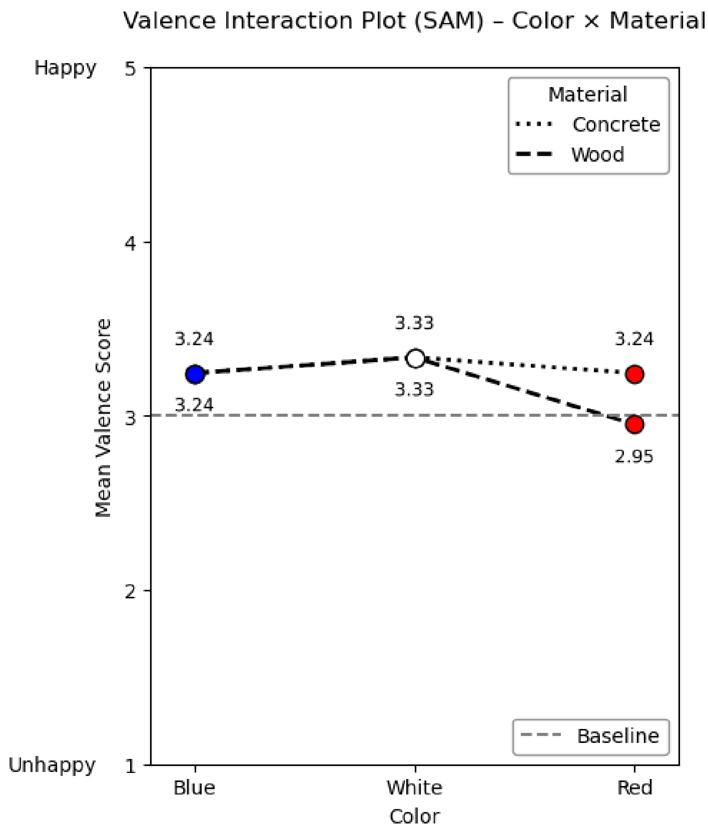

Figure 30: SAM–Valence Interaction Plot Color x Material

The Welch t–tests for valence revealed a significant gender bias for Blue scenes ($t = -2.492$, $p < 0.05$) and for Concrete ($t = -1.981$, $p = .049$), with women rating these stimuli more positively than men. No significant gender differences were observed for Red ($t = -1.105$, $p = 0.271$), White ($t = -0.937$, $p = .350$) and Wood scenes ($t = -1{,}657$, $p = .099$).

According to these findings, a three-factor Type II ANOVA including Gender alongside Color and Material was conducted. A small but significant main effect of Gender emerged, women rated scenes with overall higher valence (positive) than men ($F (1, 45) = 5.93$, $p = .015$). However, neither gender–related interaction terms (Color x Gender, Material x Gender and Color x Material x Gender) reached significance, indicating that the gender difference in valence is consistent across all Colors and both Material types.

4.2.3 Residential Background effects

Arousal

For every stimulus (Color and Material), for every residential group the values were significantly below the baseline, indicating calming effect but showed no Residential Background effect.

An additive mixed-effects model including only the main effects for Residential Background, Color and Material confirmed that Residential Background does not predict overall arousal. Relative to the Agglomeration group, City showed an increase of $\Delta = 0.072$ ($z = 0.342$, $p = .732$) and Countryside a similar increase of $\Delta = 0.073$, $z = 0.379$, $p = .705$).

The Linear Mixed effects model (MixedLM) was computed with the baseline of the combination Agglomeration x White x Concrete. For the Color Stimuli, the Residential Background revealed for the Color Blue in City vs Agglomeration a significant lower arousal for the City Group of $\Delta = -0.500$, $z = -2.243$, $p = .025$. Countryside vs Agglomeration revealed no significant difference in Blue ($\Delta = +0.156$, $z = 0.530$, $p = .596$). The Color Red revealed no significant difference, neither for City vs. Agglomeration ($\Delta = –0.083$, $z = –0.374$, $p = .709$), nor in Countryside vs. Agglomeration ($\Delta = +0.021$, $z = 0.071$, $p = .944$). Post-hoc tests revealed for Blue scenes a non-significant trend toward lower arousal in the City group compared to the Agglomeration group ($t = -1.18$, $p = .241$, $d = 0.25$) and an greater decrease arousal for City compared to Countryside ($t=1.42$, $p=0.159$, $d = 0.28$). All other paired combinations for Residential Background x Color revealed no reliable differences (Red: all pairs $p \geq .122$, $|d| \leq 0.30$, White: all pairs $p \geq .532$, $|d| \leq 0.13$)

The Residential Background x Material interaction detected no significance. City vs. Agglomeration with Δ = –0.20, z = –0.61, p = .54 and Countryside vs. Agglomeration (Δ = 0.17, z = 0.57, p = .57). Post-hoc contrasts revealed no significance for both Concrete and Wood (Wood: all pairs p ≥. 505, |*d*| ≤ 0.11, Concrete: all pairs p ≥ 0.212, |*d*| ≤ 0.21).

Valence

One sample t–tests against the neutral baseline (3.0) revealed that Valence ratings for Blue scenes were significantly greater than neutral, indicating happiness for the Agglomeration (p = .003) and Countryside group but not in the City group (p = .122). White scenes were rated significantly more positively than neutral only by City participants (p = .007), with no effect in the Agglomeration (p = .388) or Countryside (p = .096) samples. For Material Stimuli, Concrete elicited Happiness in Agglomeration (p = .001) and Countryside (.001) but not in City (p =.131), whereas Wood elicited Happiness by City (p =.014) and Countryside (p = .022) participants, with no effect in Agglomeration (p = .366).

In the additive model, Residential Background again showed no main-effect: City vs. Agglomeration Δ = –0.048, z = –0.215, p = .830 and Countryside vs. Agglomeration Δ = +0.038, z = 0.187, p = .852.

In the full interaction model (same baselines as Arousal) the Residential Background x Color effects revealed significance for Red for City vs. Agglomeration, with the Agglomeration group rating Red significantly higher (Δ = –0.697, z = –2.065, p = .039). Countryside vs. Agglomeration reached no significance with Δ = –0.427, z = –1.383, p = .167. The Blue Stimuli recorded a significant difference for City vs. Agglomeration of Δ = –0.716, z = –2.121, p = .034 and Countryside vs. Agglomeration by Δ = –0.312, z = –1.012, p = .312. However, Post-hoc contrast revealed a significance in Blue between Countryside and City with t = -2.54, p = .013 and a medium effect size of *d* = 0.49 that Countryside participants rated Blue significantly more positively than City participants. All other comparisons in Red or White were non-significant (White: all pairs p ≥ .134 , |*d*| ≤ 0.31, Red: all pairs p ≥ .417 , |*d*| ≤ 0.17)

No significant moderation of valence by Residential Background was observed for Material (City x Wood: Δ = +0.220, z = 0.651, p = .515; Countryside x Wood: Δ = –0.104, z = –0.337, p = .736). Post-hoc likewise revealed no significance for all pairs, but a trend for higher valence by Concrete among Agglomeration participants compared to City participants (t = 1.77, p = .079, *d* = 0.30). All other comparisons showed a recognizable trend (Concrete: all other pairs p ≥ .164, |d| ≤ 0.22, Wood: all pairs p ≥ .241, |*d*| ≤ 0.20).

4.3 Questionnaire Data

Similar to the self-assessment data, the questionnaire data were measured using on a Likert Scale of 1-5, for arousal (1 = very calming, 5 = very exciting) and for valence (1 = very unpleasant, 5 = very pleasant). Accordingly, the baseline level was set to 3 (=neutral).

4.3.1 Color

On arousal, participants rated in the questionnaire the White Stimuli as the least arousing overall (Md = 2.0, SD = 1.03) while Blue and Red both elicited a median arousal of 3.0. Red exhibited slightly greater variability (SD = 1.26) than Blue (SD = 1.03) (Figure 31). Compared to the baseline, one-sided Wilcoxon for White (W = 53.50, $p < .00005$) showed significant lower arousal, which indicates a calming effect for the White stimuli. Red (W = 172.00, p = .846) and Blue (W = 174.40, p = 0.899) were not significant different from the neutral baseline level, therefore no calming or exciting effect was visible.

The Friedman–test confirmed a significant effect of Color on arousal with χ^2=13.419 and p = .001. Post-hoc Wilcoxon comparisons with Bonferroni–correction showed a small, non-significant tendency for higher arousal under Red vs. Blue with W = 200.500, $p_{(corr)}$ = .246, Cohen's *d* = 0.25, a large significantly higher arousal for Red compared to White with W = 126.500, $p_{(corr)}$ = .005 *d* = 0.59 and a medium-sized significant trend for higher arousal under Blue versus White with W = 51.000, $p_{(corr)}$ =.006 and d = 0.57.

In the valence ratings, the White condition elicited the highest scores (Md = 4.0) while Blue and Red both yielded a median of 3.0 (see Figure 32). With the neutral baseline being 3.0, a one-sample Wilcoxon for White revealed a significantly higher valence with W = 115.50, $p <.005$. Blue and Red on the other hand did not have an overall effect of happiness with being not significantly different from the baseline – neither greater nor lower. Overall, variability was high, the highest for Red (SD = 1.35) followed by Blue (SD = 1.21) and White (SD = 1.05).

Friedman test across all colors confirmed no significant effect of color on valence with χ^2=2.713, and p=.258. Post-hoc Wilcoxon comparison revealed no difference between Red and Blue (W = 212.000), $p_{(corr)}$ =1.000 and no effect size (d = 0.00). Both Red vs. White (W = 134.000, $p_{(corr)}$ =.070, d = -0.381) and Blue vs. White (W = 205.000, $p_{(corr)}$ =.122, d = -0.34) indicate a medium-sized trend toward higher valence under White compared with Red or Blue, but these did not reach corrected significance.

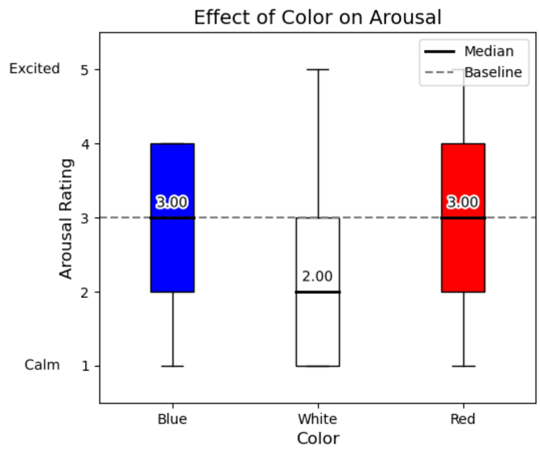

Figure 31: Boxplots of arousal by Color

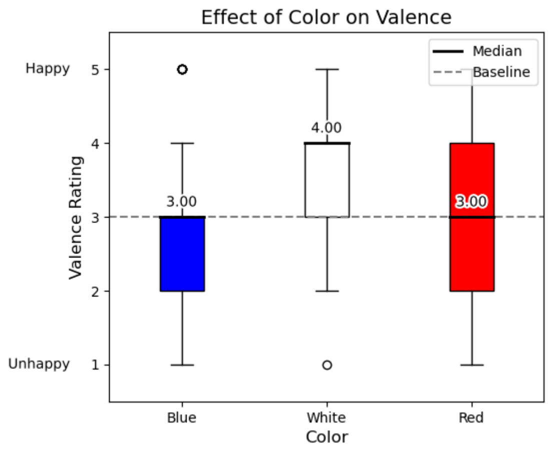

Figure 32: Boxplots of valence by Color

Testing a potential gender bias between women and men using a Mann–Whitney U test, none of the Colors, for either arousal or valence showed significance ($p > .05$). Therefore, no gender bias was detected.

4.3.2 Material

For the Material Stimuli, both Materials Wood and Concrete had equally high arousal scores, both with a median of 3.0. Variability was slightly greater for Wood (SD = 0.96) than for Concrete (SD = 0.76). One-sided t–tests showed that both Materials did not significantly differ from the baseline level. The Wilcoxon signed-rank test revealed no significant difference in arousal with W = 176.000, p = .526 and a marginal effect size of $d = 0.058$.

For the valence dimension, Wood had a higher rating than Concrete with a median of 4.0 compared to a Median of 3.0 for Concrete. A one-sample Wilcoxon test confirmed that Wood was rated significantly higher than the neutral baseline (W = 72.00, $p < .0005$) , thus indicating Wood having an effect of happiness. Concrete did not significantly differ from the neutral baseline, indicating that it did not elicit strong emotional responses. Variability was somewhat higher for Concrete (SD = 1.13) than for Wood (SD = 0.94). The Wilcoxon test showed a significant difference in valence (W = 88.000, p = .008) with a medium effect size $d = 0.463$, indicating that participants rated Wood as more pleasant than Concrete. Accordingly, the boxplots are displayed in Figure 33 and Figure 34.

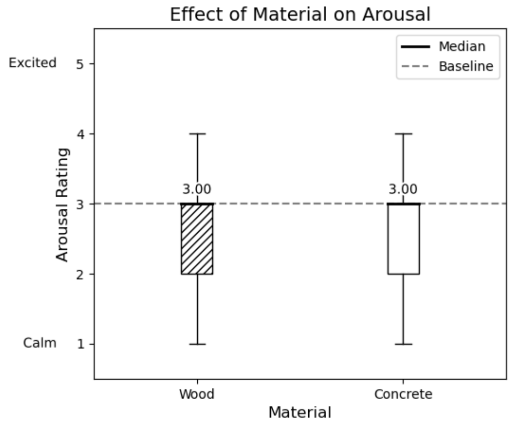

Figure 33: Boxplots of Arousal by Material

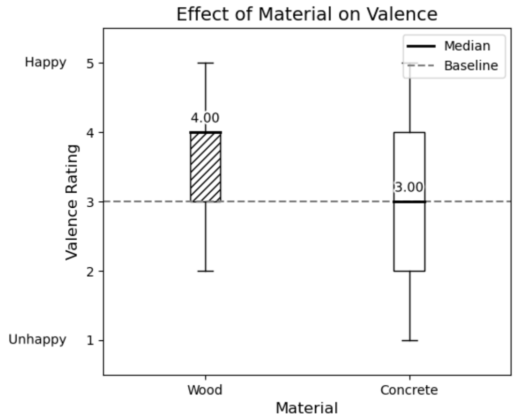

Figure 34: Boxplots of Valence by Material

4.3.3 Interaction Color and Material

In the questionnaire assessing how specific Color–Material combinations influenced participants' perception of the scenes, participants rated their experience in the VR environments on a 5-point scale: 8% reported *Not at all,* 18% *Little,* 32% *Medium*, 34% *Strong* and 8% *Very Strong.* Collapsed into 3 categories, 26% of ratings fall into the *Negative* range (no to little influence), 31% are *Neutral,* and 42% lie in the *Positive* range (strong to very strong influence). This indicates that although a sizable minority experienced minimal impact, a plurality of participants perceived clear effects of the specific Material–Color combinations (see Figure 35).

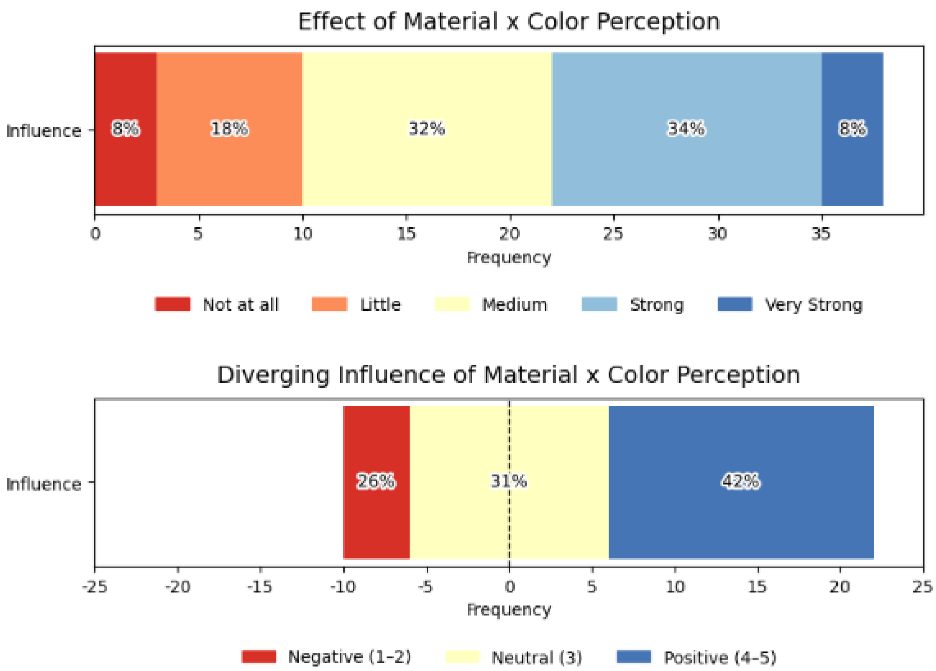

Figure 35: Bar Charts visualizing the Influence of the Color x Material Interaction

In detail, regarding preferred Color–Material pairings as shoen in Figure 36 (multiple answers were possible), Wood surfaces dominated over Concrete. White–Wood was the most preferred choice (16 votes) followed by Red–Wood (12 votes) and Blue–Wood (10). Among the Concrete combinations, only White–Concrete (10 votes) had comparably high votes as the Wood combinations. Overall, Wood was clearly the more popular material, and White the most preferred Color across both Material types.

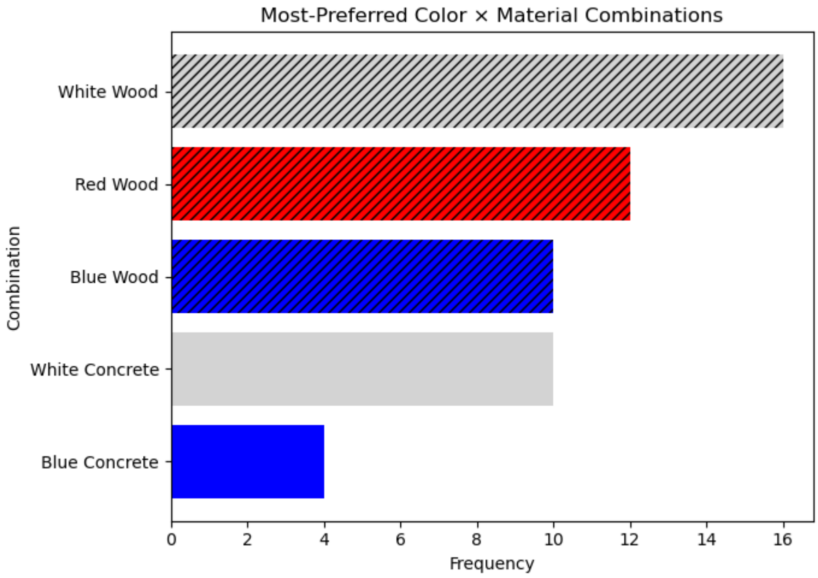

Figure 36: Bar Chart Color x Material Combinations

4.3.4 Residential Background

Arousal by Color

For Red, median arousal was highest from participants of the Countryside group (Md = 3.5) compared with those from Agglomerations and Cities (both Md = 3.0).

However, the Kruskal–Wallis test revealed no significant difference among the group, with H(2) = 2.18, p = .336. Furthermore, all Bonferroni–corrected pairwise comparisons yielded $p_{(corr)} \geq .552$. Cohen's *d* indicated medium practical effects, with the City participants rated Red scenes less arousing than the Countryside group (d= -0.50) and the Agglomeration group (d = -0.57). These trends did not achieve statistical significance. According to that, one-sample Wilcoxon did not show significance of any group being different from the neutral baseline.

For White scenes, the median arousal among the groups was identical (Md = 2.0). The Kruskal–Wallis test confirmed no reliable group difference, H(2) = 0.97 and p = .616 as well as every post-hoc tests (all $p_{(corr)} = 1.000$). Effect sizes were small to moderate – City vs. Countryside (d = 0.42) and City vs. Agglomeration ($d = 0.40$) – indicating a slight tendency for City participants to perceive White as less calming, though practically negligible between Countryside and Agglomeration ($d = 0.00$). However, one-sample Wilcoxon reached significance of a calming effect compared to the neutral baseline for Countryside ($p < 0.005$) and Agglomeration ($p < 0.01$), while for City participant no significance was visible ($p > .05$).

In the case of Blue, median arousal increased from Countryside (Md = 3.0) and Agglomeration (Md = 2.5) to City (Md = 4.0). Nonetheless, Kruskal–Wallis did not reach significance $H(2) = 4.97$, $p = .082$, and all pairwise tess were $p_{(corr)} \geq 0.113$. Cohen's d values revealed a small effect for City vs. Countryside ($d = 0.24$), a large effect for City vs. Agglomeration ($d = 1.01$) and a medium-to-large effect for Countryside vs. Agglomeration ($d = 0.70$), underscoring practical trends that warrant further study despite the lack of statistical significance. One sample Wilcoxon showed that only for Agglomeration, Blue has a calming effect ($p = .12$), while for the other two groups no difference to the neutral baseline was found.

Figure 37 shows the corresponding boxplots for Arousal by Color, grouped by participants' Residential Background.

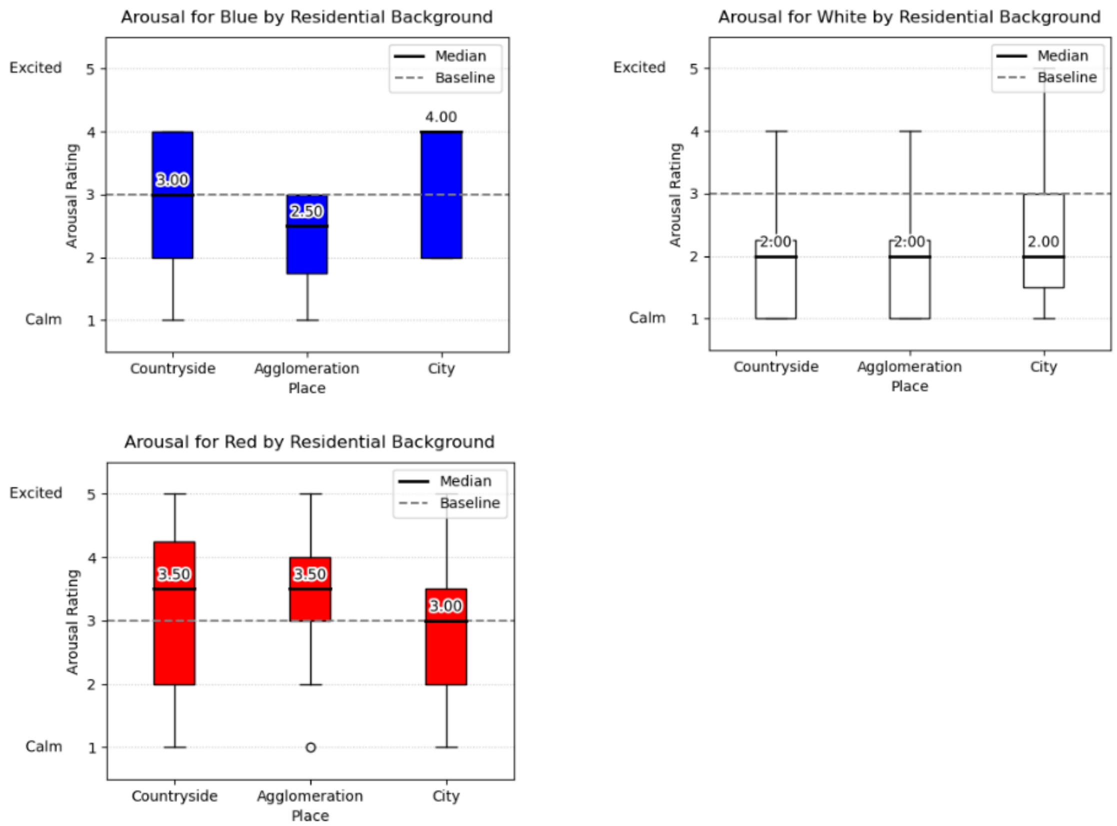

Figure 37: Residential Background Boxplots for Arousal by Color

Valence by Color

Valence ratings likewise did not differ significantly by place of upbringing. For Blue scenes, every group median was 3.0, Kruskal–Wallis yielded H(2) = 1.98, p = .372 and post-hoc $p_{(corr)}$= 1.000. Cohen's *d* suggested a medium effect for Agglomeration over City (*d* = -0.62), but this effect was not statistically robust. The other effect sizes were small or negligible. One-sample Wilcoxon–test revealed no significance difference from the baseline level.

White achieved the highest valence medians (Md = 4.0) uniformly across all categories, with H(2) = 0.50, p = .779 and all $p_{(corr)}$ = 1.000. Effect sizes were small to negligible (all |d| < 0.3), indicating that participants' Background did not meaningfully influence their positive perception of White scenes. One sample Wilcoxon–tests only revealed for the Countryside group a significant difference from baseline level indicating happiness (p = .016).

The Color Red showed matching median valence for Countryside and City (Md = 3.0) and a slightly lower valence in the Agglomeration group (Md = 2.4). With H(2) = 0.84, p = 0.657 and all post-hoc $p_{(corr)}$ = 1.000 no significance was reached. Cohen's d ranged from 0.06 to 0.39, signifying negligible to small practical differences. One-sample Wilcoxon–tests revealed no significant difference from the baseline level. Figure 38 displays the Valence by Color boxplots.

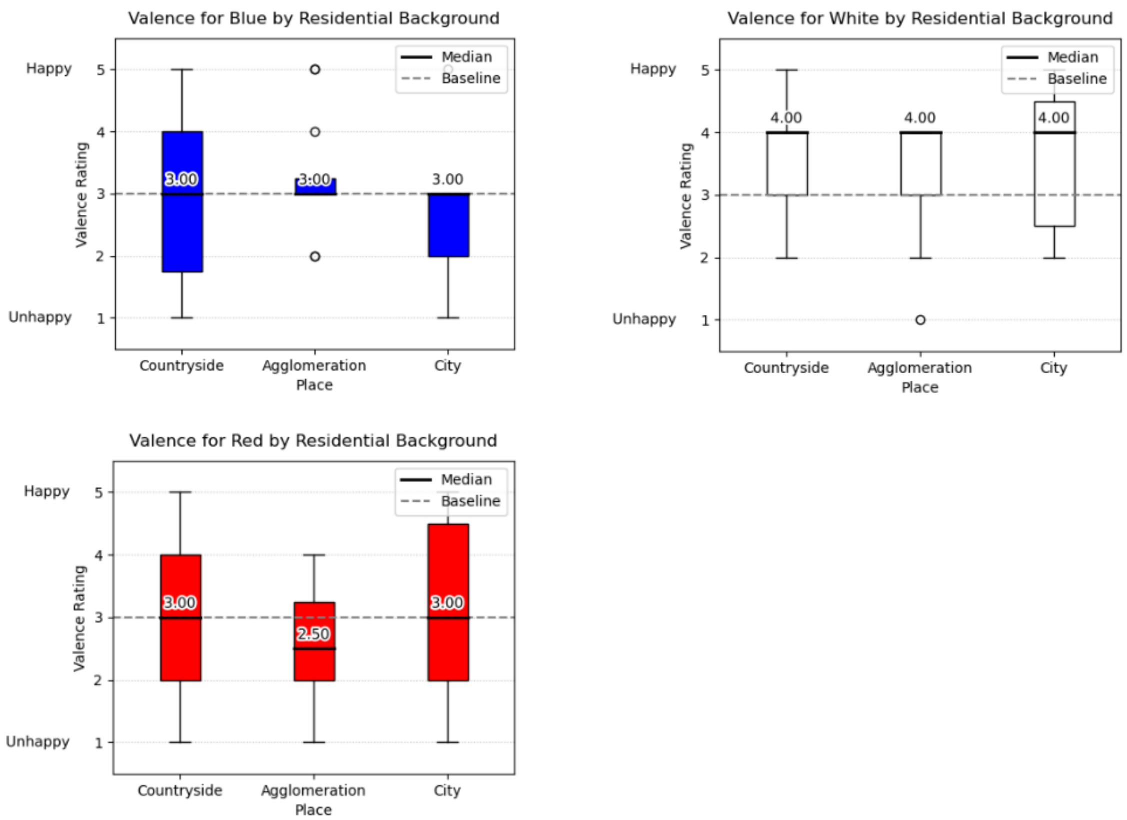

Figure 38: Residential Background boxplots for Valence by Color

Arousal by Material

For Material, Wood, Countryside reported the lowest median arousal (Md = 2.0), Agglomeration an intermediate level (Md = 2.5) and City the highest (Md = 3.0). Although this upward trend suggests higher arousal among urban-raised individuals, the Kruskal–Wallis test was not significant, H(2) = 4.25, p = .119 and post-hoc $p_{(corr)} \geq .141$. Cohen's *d* indicated large (*d* = 0.79) and medium (*d* = 0.61) practical effect for City versus Countryside and City versus Agglomeration, respectively a negligible effect between Countryside and Agglomeration (*d* = -0.13). One-sample Wilcoxon–test revealed that for Wood only Countryside showed a significant calming effect compared to baseline (p < 0.005).

In contrast, Concrete elicited median arousal values of 3.0 in the Countryside group, 2.5 for Agglomeration, and 2.0 for City. The Kruskal–Wallis showed H(2) = 2,03, p = .362 and all $p_{(corr)} \geq .508$ indicated non-significance. Cohen's *d* suggested a medium practical decrease for City versus Countryside (*d* = -0.66) and small effects for the other comparisons. One-sample Wilcoxon revealed that Concrete yielded for City (p = .012) and Agglomeration (p = .029) a calming effect, but not for Countryside (p = .921).

Figure 39 shows the arousal for Material boxplots by Residential Background.

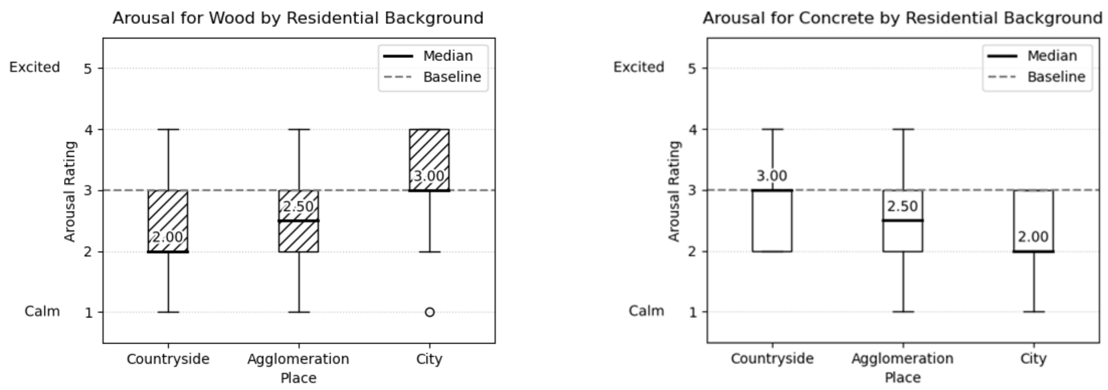

Figure 39: Residential Background boxplots for Valence by Material

Valence by Material

Wood was rated most positively by Countryside and City (Md = 4.0) and slightly less by Agglomeration (Md = 3.5). Kruskal–Wallis H(2) = 0.93, p = .624 and post-hoc corrections (all $p_{(corr)} \geq .964$) confirmed no significant differences. All Cohen's *d* effects were small or negligible (all |*d*| < 0.40). One sample Wilcoxon revealed a significant exciting effect of Wood for Countryside (p = .011) and Agglomeration (p =.023) but not for City (p = .079).

Concrete showed medians of 3.0 for the Countryside and Agglomeration groups but only 2.0 from City participants. Although Kruskal–Wallis ($H(2) = 3.67$, $p = .160$) and corrected pairwise $p_{(corr)} = .282$ showed non-significance, Cohen's *d* effect sizes were medium-to-large (City vs. Countryside/Agglomeration $d \approx -0.70$) pointing to lower valence for City respondents. Countryside vs. Agglomeration showed negligible effect ($d = 0.09$). One sample Wilcoxon revealed only for the City group ($p = .042$). a calming effect for Concrete (significant below baseline). Figure 40 displays the valence for Material boxplots by Residential Background.

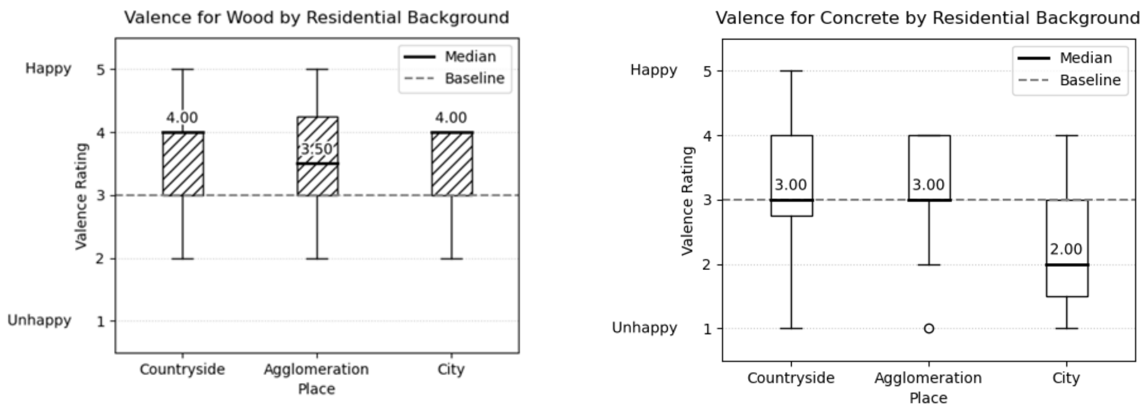

Figure 40: Residential Background boxplots for Valence by Material

5. Discussion

This chapter interprets and contextualizes the main findings of the study. It situates the results within existing theories and empirical research of building aesthetics and environmental psychology. Furthermore, the discussion outlines implications for planning practice, acknowledges limitations and answers the research questions and hypotheses.

5.1 Emotional Effect of Color

This section analyzes the emotional impact of façade colors in rural Swiss environments based on the physiological and self-reported results. The interpretation evaluates these findings in relation to **RQ1** and **H1** and situates them within the existing literature and theories.

5.1.1 Objective Physiological Measurements

Objective measurement results revealed that for color perception, phasic nSCR is a more reliable indicator than mean AUC or tonic measures taken over a time period. nSCR revealed a clear significant color effect while AUC either showed inconsistent results, in some cases even opposite to nSCR, suggesting it may be a less reliable indicator of color effects in the context of this study. According to Braithwaite et al. (2013), these findings indicate that building color did not influence the overall ambient rural environmental conditions. Therefore, it can be suggested that façade colors act as a discrete visual effect, eliciting short-term physiological responses, rather than functioning as a long-term factor of the perceived landscape aesthetics.

ART ANOVA further revealed a main effect on color. nSCRs differed significantly by façade color, with Blue and Red producing higher arousal (more nSCR peaks) than the neutral white façades, with medium effect sizes. These results confirm the assumption of **H1** that colored surfaces induce higher emotional arousal than neutral surfaces. However, Red and Blue did not differ significantly from each other. Notably, the variance in the White condition was lowest, suggesting that neutral façades are perceived more consistently across individuals, whereas colored façades evoke more variable responses. This is in line with literature, likely due to individual differences in color perception and preference (Manav, 2017).

The higher arousal induced by Red compared to White is consistent with classical theories of Le Corbusier and contemporary findings, where Red, as a representative of warm colors is associated with attributes like “liveliness”, “warmth” or “energy”. This typically leads to higher physiological activation (De Heer, 2009; Wang et al., 2024a). In this regard, the present findings in rural Swiss environments align with studies conducted in urban landscapes and outside of Switzerland.

By contrast, the finding that Blue and Red elicited similar physiological arousal may not capture the warm–cool color distinction. Consequently, the calming–exciting difference emphasized in classical theories and several contemporary studies was not observed in the physiological data. Rather, the results may reflect contextual unfamiliarity. In rural Switzerland, large façade areas in intense blue or red hues are relatively uncommon, whereas earthy tones, as already highlighted by Le Corbusier or current planning regulations, are more typical (Bundesamt für Kultur (BAK), 2020; De Heer, 2009). Le Corbusier also emphasized that more dynamic colors can provoke strong emotional engagement, which may account for the heightened arousal responses observed for both Blue and Red (Jaglarz, 2024). Furthermore, color harmony with the surrounding context could have been affected (O'Connor, 2006). In a predominantly natural environment with high proportions of green, Blue façades stand out more strongly than they would in other research context like urban environments.

Importantly, the higher arousal of Blue does not necessarily contradict the assumption of **H1** that Blue is more calming than warm hues. According to Bower et al. (2022), Blue can in Virtual Reality be physiologically activating while nevertheless being perceived as calming on a subjective level. This suggests that physiological arousal does not necessarily reflect agitation or excitement. Rather, it may capture increased attention or perceptual salience, which can coexist with a calming subjective appraisal. Therefore, the color effect on emotions cannot be fully addressed by physiological measurement alone and is discussed in relation to the subjective measurements in the following section.

5.1.2 Subjective Measurements

The subjective arousal ratings generally follow the patterns observed in the EDA data. In the SAM results, both Red and Blue façades elicited significantly higher arousal than White, consistent with **H1**. However, unlike the physiological findings, SAM data further indicated that Red produced significantly higher arousal than Blue. Nevertheless, SAM also showed that all tested colors were rated as significantly calming compared to the neutral baseline. Thus, the specific prediction of **H1** that Red would evoke a distinct exciting effect was not supported, even though its arousal ratings were significantly higher than those of the other color stimuli (Wang et al., 2024a). In turn, the calming effect of Blue reported in previous studies was confirmed in the SAM results.

The questionnaire results on arousal were consistent with the physiological measurements, with Red and Blue not differing significantly from another. However, both hues were perceived as neutral in terms of arousal, neither calming nor exciting. This divergence from the SAM result indicates, that while Blue may evoke calming impressions in the immediate experience, such effects are less robust in retrospective evaluations. This aligns with the distinction by Diener & Emmons (1984). Such divergences may further indicate, that intense hues like Blue, may elicit an immediate calming impression, which is not always sustained in more deliberate evaluations.

Variability in ratings for both Red and Blue was again higher than for White, reinforcing the notion that individual perception of colored façades varies substantially (Kuppens et al., 2013; Whitfield & Slatter, 1978). The variability likely contributed to the neutral overall ratings. While some participants may indeed have experienced Red as exciting or Blue as calming, others did not, resulting in an averaged effect close to neutrality.

Taken together, these findings suggest that the exciting effect typically associated with Red and the calming effect associated with Blue are not consistently observed across the study group for rural Swiss areas. Accordingly, H1 cannot be confirmed, although some evidence for these patterns emerged (e.g. Blue in SAM), the effects were not robust across all measures or individual.

Overall, the interpretation of the subjective results is consistent with the conclusions drawn from the physiological findings in Section 5.1.1. Regarding **RQ1**, façade color does influence arousal, but not in the clear warm–cool pattern posited from theory. Instead intense colored façades in Swiss rural environments appear to be perceived as relatively unfamiliar stimuli, eliciting more variable and less predictable responses than the neutral White façades. This highlights the importance of contextual familiarity and color harmony in shaping emotional responses, rather than universal associations of color categories.

The valence results support the interpretations drawn from the arousal data. White was consistently rated as significantly more pleasant than the baseline across both subjective methods, reflecting its relatively stable perception among the participants compared to the intense hues of Blue and Red. By contrast, Blue again showed divergent results across the two methods – pleasant in the SAM but neutral in the questionnaire – while Red was neutral in both. These findings are consistent with the interpretation that intense hues do not produce robust effects and have high inter–individual variability. This align with literature suggesting that intense colors often polarize viewers. For instance, Red may carry dynamic or energetic associations as

Radwan (2015) state, while for others it may evoke warning or visual disturbance (Shikata & Matsui, 2025).

Taken together, the findings indicate that the dimension of color hue alone, without considering the dimensions of saturation or lightness is insufficient to confirm systematic emotional warm–cool effects in rural Swiss environments. Importantly, the responses of Blue and Red did not manifest as a negative emotion (i.e. high arousal combined with low valence) but rather as neutral to mildly pleasant appraisals.

5.1.3 Evaluation of Research Question 1 and Hypothesis 1

With respect to **RQ1**, effects of façade color on arousal were partially found. The questionnaire data indicated that both Red and Blue elicited higher arousal than White, which is consistent with **H1**. However, Red and Blue did not differ significantly from one another and were overall perceived as neutral in terms of arousal. This does not support the specific prediction of an "exciting Red" or a "calming Blue" effect.

In the SAM data, as hypothesized, both Red and Blue again elicited higher arousal than White. The calming effect of Blue provided partial support for **H1.** However, Red once more failed to be perceived as exciting.

The EDA results further confirmed the higher arousal for Blue and Red compared to White. This is in line with **H1**. No significant difference in physiological arousal emerged between Red and Blue. However, this cannot resolve the hypothesized distinction without subjective measures, as high physiological arousal does not necessarily equate to agitation.

Overall, the findings suggest that emotional arousal of façade colors in rural Swiss contexts is shaped more by contextual familiarity and color harmony than by the warm–cool distinction. As a result, the responses were predominantly neutral–to–calming rather than strongly arousing.

5.2 Emotional Impact of Material

This section examines **RQ2** and **H2**, drawing on both objective and subjective results. The analysis addresses whether Wood as a proxy of a natural material evoke more positive affective responses than Concrete as a higher-processed material, as posited in **H2**. These findings are situated within the broader literature on material aesthetics regarding the concepts of naturalness and immateriality.

5.2.1 Physiological Measurements

The EDA data revealed significant interaction between material and color, implying that the physiological arousal evoked by a color is not contingent upon the material on which it is applied. In other words, material and color appear to influence arousal independently in the context of this study.

This outcome contrasts with **H2** and the theoretical concept of immateriality that a color's emotional impact depends on the material's properties like texture and roughness (Hill, 2006; Löschke, 2016). The findings of the physiological measures suggest, that color retains a consistent effect regardless of material. One potential explanation for this result is the technical limitations of VR. Critical immaterial factors such as texture roughness, thermal comfort or acoustic qualities, which are central to material-mediated perception are difficult to simulate effectively. Consequently, subtle material–texture differences may not be visible, limiting their physiological impact.

However, the two materials Concrete and Wood differed significantly, with Concrete eliciting significantly more nSCRs. This indicates that material exerts an independent discrete visual influence on physiological arousal, even if no interaction with color was observed. In other words, while color maintains a consistent effect regardless of the underlying material, material itself shapes building perception on a physiological level. Importantly, with respect to **RQ2,** this does not exclude the possibility that subjective evaluations capture Color x Material interactions more sensitively, particularly because they also reflect valence. Thus, the inclusion of subjective assessments (SAM and questionnaires) is essential to fully understand the emotional impact of material and its interplay with color.

5.2.2 Subjective Measurements

The SAM results indicate that both Wood and Concrete were rated significantly below the neutral baseline on arousal, suggesting a general calming value across materials. Consistent with physiological arousal, there was no overall significant Color x Material interaction on arousal. However under Red, accordingly to **H2** a material effect emerged. Red–Wood elicited significantly higher arousal than Red–Concrete, while remaining below baseline. This selective interaction for Red was also visible in valence and strengthens the inference that a material effect on color exists when paired with Red. Valence, which was initially significantly positive for both materials relative to baseline, dropped below the neutral baseline for Wood in the Red condition. This interactions in arousal and valence were evident only for Red and not for the other Color Stimuli.

The interactions are most likely attributable to differences in the way Red appeared across Materials in the VR environment. In the Red condition, the color appeared markedly more vivid and saturated on Wood than on Concrete, making it more visually striking (see Figure 41). This pattern was not as pronounced for Blue or White, where the visual appearance of the color was relatively consistent across material textures. Such a result supports the existing literature view, that warm, highly salient hues like Red are more sensitive to the surface carrier's perceptual properties (Manav, 2017).

Figure 41: Similar House with Red–Wood Façade (left) vs. Red–Concrete Façade (right)

Red–Wood failed to elicit either a calming effect or a positive valence, whereas Red–Concrete was both calming and happiness–inducing. This can be explained by recent research of color perception. Higher saturation and brightness in a color is a quality with higher arousal and reduced aesthetic appraisal (Bittermann, 2018; Wang et al., 2024a). By contrast, on Concrete the same hue appeared more muted and integrated, resulting in a stronger aesthetic preference. This aligns further with findings by Høibø (2018), who reported a general preference for concrete façades over wooden ones. Particularly in urban contexts and multi-story buildings, concrete was rated more harmonious and familiar. While the VR environments in this study depicted single-family houses, the positive perception of Concrete might reflect an attribution of "stability" and "robustness". This finding might be independent of building type or location (urban –

rural). Importantly, in rural Switzerland both wood and concrete are common façade materials, reducing the likelihood that unfamiliarity is responsible for differences (Der Bundesrat, 2024).

However, the questionnaire results diverged from the SAM findings. In the questionnaire no significant arousal difference were reported. Only valence ratings revealed a significant preference for Wood over Concrete. Participants' rankings of preferred Color–Material combinations further reflected this tendency, with all top choices featuring Wood, most frequently White-Wood, followed by Red–Wood and Blue–Wood. In terms of perceived influence of Material on color appearance 42% of participants reported perceiving a strong to very strong influence, 32% perceived a moderate influence and 26% reported little to no influence. These data suggest that while the majority consciously perceived a material effect, a notable minority did not register such differences.

The post-hoc preference for Wood is consistent with the literature on perceived naturalness. Natural materials such as Wood are often associated with reduced environmental impact, health benefits, more value and aesthetic appeal. Such associations appear to be deeply embedded in participants' mental models, shaping retrospective preference judgements even when the immediate VR experience did not prompt strong material differentiation. This discrepancy between in-situ responses and retrospective evaluations was also found in the subjective results for the color stimuli and is again in line with previous findings (Diener & Emmons, 1984). Therefore, post-reflective judgement processes in the field of building aesthetics can reintroduce normative idealized concepts absent from momentary perception.

From a practical perspective, these findings imply that Material x Color interactions are relevant for rural building design, but the appear to be rather selective than universal. The clearest evidence emerged for Red, representing warm colors. There, surface reflectance and saturation differed strongly between Wood and Concrete, producing distinct emotional outcomes. By contrast, cold (Blue) and neutral (White) colors did not show comparable interaction effects. This absence may be partly attributable to the limitations of VR, but it also reflects a more general tendency for cold and neutral hues to be less sensitive to material carries with respect to immaterial factors like reflectance and light.

These results highlight that, in practice, the interaction between materials and warm colors require particular attention. Such combinations can strongly affect visual qualities such as lightness, reflectance and saturation in real–world contexts. By contrast, cold and neutral hues seem less sensitive to material carriers. The general preference for natural materials like wood cannot be confirmed. Although retrospective responses supported **H2**, immediate responses did not consistently do so and in some cases even contradicted it. Therefore, preferences for façade materials should not be assumed categorically but assessed case by case, with specific attention to the Material–Color combination in its actual design context.

5.2.3 Evaluation of Research Question 2 and Hypothesis 2

Regarding **RQ2,** Color x Material interactions were partially found. The questionnaire data revealed a significant preference for Wood over Concrete in valence ratings and in the ranking of preferred Color–Material combinations, which is consistent with **H2**. However, the SAM data showed a different pattern. Only in interaction with Red did the Material Stimuli produce significant effects. Red–Concrete was rated calming and happiness inducing, whereas Red–Wood was rated neutral for both arousal and valence. These results do not support the hypothesized patterns of **H2**. The physiological EDA results further diverged, with Concrete eliciting higher arousal than Wood, but independent of Color.

Taken together, the findings suggest that the emotional impact of façade materials is shaped by immaterial qualities, such as reflectance and saturation, as well as by culturally embedded associations of naturalness that inform retrospective evaluations.

5.3 Emotional Effect of Residential Background

In this section, the influence of Residential Background on emotional responses is examined. In this thesis, Residential Background was defined by the place of upbringing. This measure was chosen instead of current place of residence, as the latter was skewed towards a predominantly urban distribution, a factor that should be taken into account.

Although Hermann et al. (2021) suggested that individuals often perceive their environment as more rural than official classifications indicate, a comparison between self-reported upbringing and the objective classification (see Section 3.2.2) revealed almost identical distributions. This indicates that participants in this study did not systematically perceive their residential background as more rural than officially defined. The following analysis addresses the results in relation to **RQ3** and **H3**.

5.3.1 Physiological Measurements

The EDA data supported **H3** revealing a clear effect of Residential Background on autonomic arousal. Participants who grew up in urban settings (the City group) exhibited consistently and significantly higher nSCRs across all VR-scenarios than those raised in rural areas (the Countryside group), with the Agglomeration group falling in between. Importantly, the difference between the groups was not an effect either for Color (Red, White, Blue) nor Material (Wood, Concrete). This indicates no condition-specific modulation of physiological arousal. These findings are consistent with the broader Swiss urban-rural divide documented by Hermann et al. (2021, 2023) and suggests that cultural differences play a role in the different emotions towards landscapes.

The detected pattern aligns with the class *orienting/novelty framework* originally described by Sokolov (1963). According to his model, any new or unexpected stimulus evokes coordinated set of physiological changes like skin-conductance peaks (SCR), heart-rate deceleration and pupillary dilation, that habituate upon repeated exposure (Bradley, 2009). Thus, the assumption can be made that the City participants felt the rural environments were inherently more novel, eliciting stronger orienting-related EDA peaks. By contrast, Countryside participants were already familiar with such settings and showed correspondingly blunted responses. This resonates with Wartmann et al. (2021) and Ströbele & Hunziker (2017), who stated that place attachment leads to stronger affective familiarity.

Moreover, Sokolov's orienting response is explained purely by novelty detection. Therefore, it predicts that arousal will increase whenever a stimulus is perceived as unfamiliar, independent of its specific features (Bradley, 2009). This is confirmed by the results of this study, as the specific Color and Material Stimuli had no influence on the Residential Background difference. In other words, the significantly higher number of nSCR in urban-raised participants can be attributed to their relative unfamiliarity with rural environments rather than to any specific visual feature of the stimuli.

5.3.2 Subjective Measurements

The results of the SAM did not confirm **H3**, but showed that on the arousal scale all colors and materials yielded ratings significantly below the neutral baseline, confirming a broadly calming effect, regardless of the residential background. In other words, even though City showed larger electrodermal responses, they still felt the rural VR scenes to be calming. Importantly, there were no overall differences in SAM-reported arousal between City, Agglomeration and Countryside. Overall, no systematic differences in SAM–reported arousal were found. One exception appeared, with City participants rating Blue façades more calming than Agglomeration participants. However, this isolated effect cannot be clearly explained in light of the cultural and spatial similarities between the two groups and should therefore be interpreted with caution. Accordingly, the questionnaire data did not reveal systematic variation in arousal by Residential Background. This confirms the absence of robust differences, thereby further failing to support **H3**.

For materials, a more interpretable tendency in line with **H3** emerged. Wood was perceived as significantly calming only by Countryside participants, whereas Concrete produced calming effects particularly for both City and Agglomeration. This pattern follows the principle of *Place Attachment* (Wartmann et al., 2021). Thus, individuals raised in rural Swiss areas are typically more surrounded by wooden structures like barns or farmhouses (Bundesamt für Kultur (BAK), 2020) and thus associate wood with comfort and nostalgia, yielding a calming, place-attached response. Conversely, Concrete as more of a representer of urban environments, confers a sense of familiarity and stability for City and Agglomeration. Nevertheless, direct pairwise comparisons yielded no significant differences, so these effects remain tentative.

On the valence dimension of the SAM, no stimulus was rated negatively by any group. Some scattered effects appeared (e.g. Blue rated more positively by Countryside than City), but no consistent cross–group pattern emerged. In the questionnaire, Wood was rated positively in Countryside, which broadly reflect place–related associations, as wood is a familiar and valued material in rural settings (Bundesamt für Kultur (BAK), 2020; Kanton Glarus, 2022). By contrast, Concrete was perceived negatively by City participants. This suggests that, rather than being associated with stability or familiarity as reported in Norway by Høibo et al. (2018), concrete in Switzerland may be linked to overexposure in urban contexts, where it is perceived as excessive and aesthetically less appealing (Hermann et al., 2023).

Importantly, no single stimulus produced identical outcomes across both SAM and questionnaire measure. This discrepancy may reflect the differential reliability of in-moment SAM rating versus retrospective questionnaire judgements regarding cultural influences by place on material and color perception. Consequently, it remains questionable whether Place Attachment framework*s* (Wartmann et al., 2021) exert a decisive influence on the aesthetic evaluation of façades in rural Switzerland. Accordingly, the inconsistent findings especially for valence, likely arise from the split between immediate affective reactions and reflective cultural associations (Diener & Emmons, 1984; Solhan et al., 2009). Thus, the evidence for **H3** in subjective evaluations remains inconsistent.

5.3.3 Evaluation of Research Question 3 and Hypothesis 3

Overall, according to **RQ3** effects of Residential Background on emotional responses were only partially found. The questionnaire data did not reveal systematic variation in arousal. Some tendencies appeared, but no robust group differences emerged. Thus, the results do not support **H3.**

The SAM data similarly failed to confirm **H3.** All groups rated the VR scenarios as calming, regardless of their background. An isolated effect emerged with City participants rating Blue façades as significantly more calming than Agglomeration participants, but this result lacks a clear explanation and should be interpreted with caution.

By contrast, the physiological EDA data supported **H3**. Urban–raised participants showed consistently higher autonomic arousal than those from rural backgrounds, with Agglomeration falling in between. Importantly, this effect was independent of Color and Material Stimuli.

Taken together, the physiological results align with the orienting–novelty framework, suggesting that urban–raised individuals experience rural environments as more novel and arousing. The absence of consistent effects in subjective measures highlights that reflective appraisals and cultural associations dilute these physiological differences.

5.4 Implications for Rural Planning in Switzerland

This section synthesizes the findings in relation to rural planning practice in Switzerland. Across **RQ1 – RQ3** the results point to implications for façade design guidelines in rural Switzerland. In particular, they suggest, that current regulations on colors and materials could benefit from a more flexible and evidence-based approach, rather than relying primarily on traditional assumptions about rural building environments.

With respect to **RQ1** (Color), the findings showed that while White emerged as the most consistently calming and positively evaluated façade color, even strong saturated hues such as vibrant Blues and Reds did not elicit negative responses, but rather neutral to partly positive ones. This suggests that the current practice of broadly discouraging vibrant and bright colors in village central zones may not be empirically justified. Most existing planning regulations do not impose absolute prohibitions, but instead use advisory wording such as "avoid bright colors" or “prefer earthy tones” to ensure harmony with the surrounding landscape. However, the results indicate that *color harmony* in rural Switzerland should not be equated exclusively with muted or earthy tones.

Even saturated and bright colors like Red or Blue can contribute to visual coherence when contextually integrated. Responses appear to be more strongly shaped by unfamiliarity than by an inherent lack of harmony. Moreover, the traditional dichotomy of warm versus cool colors, rooted in classical theories such as Le Corbusier’s and reinforced in contemporary studies in urban contexts, may be too rigid for contemporary rural planning in Switzerland.

For materials (**RQ2**), the results suggest that both Wood and Concrete can be perceived positively. The role of the material as a surface carrier is particularly relevant for warm hues such as Red, where differences in reflectance and saturation produced distinct emotional outcomes. By contrast, cool (Blue) and neutral (White) hues appeared largely unaffected by the underlying material. This indicates that a prescriptive prioritization of one material over another in planning regulations – *e.g. favor Wood over Concrete* – may not be warranted in general. Especially for warm hues like Red, careful attention to the overall design composition and its interaction with the surrounding landscape is needed to create pleasant environments.

Finally, regarding **RQ3** (residential background), physiological differences between urban- and rural raised participants suggest that familiarity influences immediate autonomic responses. However these difference did not consistently translate into subjective aesthetic preferences for a specific stimuli. This suggests that, unlike the broader “urban-rural divide” visible in Swiss political debates, cultural background of the inhabitants does not provide strong justification for differentiated planning rules. For planning practice, this implies that design guidelines do not need to be tailored separately for urban– or rural–raised populations. Instead, emphasis should be placed on universal principles such as contextual integration, color–material coherence, and harmony with the surrounding landscape, which appear to guide aesthetic evaluations across all groups.

Overall, the findings suggest that planning practice should critically rethink the definition of *visual harmony* in rural Switzerland. Instead of relying on blanket discouragement of certain hues or categorical preferences for specific building materials, guidelines could place greater emphasis on contextual integration, material–color combinations and coherence with the surrounding landscape. Such an approach would preserve the distinct character of rural environments while allowing more design flexibility for architects and residents. However, these implications need to be considered in light of the study's methodological limitations which are discussed in the following section.

5.5 Limitations

This chapter discusses the limitations of the present study in relation to the interpretation of its findings.

A first limitation concerns the sample size and composition. Recruitment was conducted mainly at the University of Zurich, resulting in a relatively homogeneous participant pool. The age of the participants ranged between 21 and 29, thus representing predominantly young adults. Furthermore, the majority of participants reported living in urban areas. Gender effects were tested and, while some significant differences appeared (e.g. SAM higher valence for Concrete), they did not affect the main analyses related to the research questions. However, an age-related bias remains possible. Previous research has shown clear a differences in color perception across age groups (Sengupta et al., 2020; Van Leeuwen et al., 2023). For instance, van Leeuwen et al. (2023) demonstrated that older adults tend to perceive saturated colors as less vivid.

Furthermore, G*Power indicated that the sample size was sufficient for the given study design. Still some effects, particularly those involving the Residential Background groups, were of medium magnitude yet failed to reach statistical significance. This suggests that the sample may have been too small to reliably detect certain differences. Therefore, future research should employ larger and more demographically representative samples covering the full population spectrum to provide a more comprehensive understanding of preferences and to derive robust planning guidelines.

A second limitation relates to technical constraints of virtual reality setup. While Unreal Engine enabled the creation of realistic scenes, the fidelity of texture details and rendering quality was reduced in the HMD, despite enhanced immersion and depth perception. For example, while tree leaves moved naturally on the desktop in Unreal Engine, they appeared as a pixelated flicker within the VR headset. Dynamic shadows and lighting conditions were also displayed with reduced realism and grass had to be excluded due to performance issues (compare Figure 42). As texture realism plays a crucial role in the perceived relationship between color and material, these limitations may have influenced the results.

More generally, VR technology remains an abstraction of reality, and earlier studies have been reported similar challenges. Magalhães et al. (2023) suggest that immersion can be enhanced through multisensory inputs (e.g. adding auditory or olfactory cues) alongside visual stimuli. While such approaches exceed the scope of this study, they may yield more results that are closer to real-world experiences in future work. Despite these constraints, the present experiment revealed significant effects that allow for meaningful conclusions.

Figure 42: Red–Concrete Environment before VR Integration (left) vs. Final Version (right)

Another limitation is that neither time of day nor season was considered, although both factors can influence the perception of color and material. For example, colors may appear different at night compared to daylight (Lanini-Maggi et al., 2024). Moreover, the study's stimuli focused exclusively on the hue dimension of color, while saturation and lightness are also key components that can shape perception. Future research could incorporate these dimensions to develop more comprehensive façade color guidelines for rural settings.

Finally, Switzerland is geographically and culturally diverse. Even within rural areas, environmental and building characteristics vary considerably, for example alpine villages in mountainous regions or small so-called *"Weiler"* locally outside of official building zones. Such contextual differences may shape color perception and aesthetic evaluation, limiting the generalizability of the present findings. While a preliminary analysis of rural building regulations was conducted, the VR environments used in this study cannot be assumed to represent all rural contexts in Switzerland.

In conclusion, while the present experiment has several limitations that should be addressed in future research, it nevertheless provides novel insights into field of building aesthetics.

6. Conclusion

This thesis set out from the observation that rural building regulations in Switzerland often restrict design freedom by discouraging strong façade colors or prescribing specific façade materials, with the stated aim of preserving visual harmony. The central question was whether these normative assumptions about color and material effects are empirically supported in rural Swiss contexts. Situated within the research field of Cognitive Architecture, emotional responses were conceptualized along the dimensions of arousal and valence. In the context of rural design practices in Switzerland, this thesis provides an empirical research perspective on whether the assumptions of current rulemakers are reflected in reality.

The research questions addressed three aspects: the perception of façade colors, the perception of materials in interaction with colors and the role of participants' residential background. To answer these questions, a controlled experiment was conducted in Virtual Reality. All participants were exposed to every combination of Color x Material x Location and subsequently classified according to their upbringing (City, Agglomeration, Countryside). Emotional responses were captured by combining physiological measurement of electrodermal activity (EDA) and two subjective methods. The Self-Assessment Manikin (SAM) to capture immediate, state-like affect, and a questionnaire to capture more reflective, trait-like affect. While EDA measured arousal, the SAM and questionnaire assessed both arousal and valence according to the definition of emotion applied in this thesis.

Correlation was found between physiological and subjective measures, but systematic divergences also emerged between the subjective methods, in line with existing theories. The results showed how multiple measurement methods capture different facets of emotional responses in building aesthetics.

Façade Color **(RQ1 & H1)** produced significant differences in physiological arousal. However, subjective measures indicated that these effects were modest – ranging from calming to neutral – and importantly, not associated with negative valence. White façades, which represent the standard in current rural planning practice, were evaluated most positively. Red and Blue did not evoke negative responses that would empirically justify the discouragement or exclusion of such colors in planning guidelines. Moreover, the classical warm–cool distinction was not reliable in this study. Red was not “exciting” and Blue was only partially “calming”. Instead, responses appeared to be shaped by contextual familiarity and visual harmony with the surrounding landscape.

For Material **(RQ2 & H2),** the findings indicated a partial role in shaping color perception. Material mattered particularly for Red – representing warm hues – where differences in reflectance and saturation produced distinct emotional outcomes between the materials. By contrast Blue (cold) and White (neutral) hues were less affected by the underlying material.

Regarding Residential Background **(RQ3 & H3)**, physiological arousal showed consistently higher autonomic arousal among urban–raised participants than among rural–raised participants, yet these differences did not translate into consistent or significant differences in aesthetic preference across Color or Material Stimuli.

Overall, the findings suggest that rural planning practice should reconsider “visual harmony” as defined in current façade guidelines. Rather than relying on blanket discouragement, guidance should emphasize contextual integration, color–material interplay and coherence with the surrounding landscape. This would allow greater flexibility in façade design while still maintain the rural character of Swiss villages.

Consequently, further research in this field remains necessary. Future experiments could extend the present findings by testing additional hues along the warm-cool spectrum (e.g., orange, green) or by including other façade materials (e.g. stone, glass). Other additions in this field of research would be the inclusion of other dimensions of color (saturation and lightness) or considerations in variation across time of day, weather and season. Moreover, the diverse range of rural settings in Switzerland has not yet been fully represented. Comparable studies in specific alpine villages, “Weiler” located outside official building zones, or across different zoning categories (“Wohnzone”, “Arbeitszone”) could provide a more comprehensive picture of rural building scapes. Cross–country comparisons could assess whether the patterns observed in Switzerland hold true in other cultural contexts.

Beyond Color and Material, building aesthetics are also dependent on position, composition and spatial integration. Including these aspects may reveal further insights into rural architecture. Methodologically, improving VR fidelity and considering multisensory approaches or navigable virtual villages could yield clearer and more robust results. Broadening the study group – e.g. by age and cultural background – would help ensure that aesthetic guidelines do not overlook groups who also inhabit rural areas in Switzerland. Finally, expanding emotion measurement beyond EDA (e..g EEG or eye-tracking) and advancing objective valence indicators would deepen the understanding of perceptual and affective processes.

Overall, this thesis provides an initial but important empirical step toward understanding façade aesthetics in rural Switzerland. By combining immersive VR with physiological and subjective measures, it demonstrates both the potential and the challenges of empirically grounding planning regulations in aesthetic perception. While the study cannot claim universal validity, it highlights the value of integrating emotional and perceptual dimensions into spatial planning and design practice. In doing so, it contributes to an ongoing dialogue about how rural character can be preserved without constraining creative design solutions, ultimately fostering environments that are both culturally rooted and emotionally resonant.

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Appendix

A – Land Cover Analysis and Building Ordinances

GIS Analyse:

Zone	Municipality	Canton	Building Area	Green Space	Sealed Surface
1	Walenstadt	St. Gallen	0.28	0.09	0.63
2	Walenstadt	St. Gallen	0.30	0.25	0.45
3	Engelberg	Obwalden	0.50	0.09	0.41
5	Arosa	Graubünden	0.39	0.38	0.23
6	Arosa	Graubünden	0.35	0.47	0.18
7	Seengen	Aargau	0.18	0.40	0.42
8	Seengen	Aargau	0.28	0.35	0.37
9	Oberems	Wallis	0.32	0.51	0.17
10	Giswil	Luzern	0.47	0.38	0.15
11	Giswil	Luzern	0.40	0.31	0.29
12	Därstetten	Bern	0.32	0.40	0.28
14	Ins	Bern	0.31	0.41	0.28
15	Ins	Bern	0.33	0.38	0.29
16	Wäldi	Thurgau	0.26	0.51	0.23
17	Fischenthal	Zürich	0.17	0.44	0.39
Summary			**⌀ = 0.277**	**⌀ = 0.358**	**⌀ =0.318**
			≈ 0.3	**≈ 0.4**	**≈ 0.3**

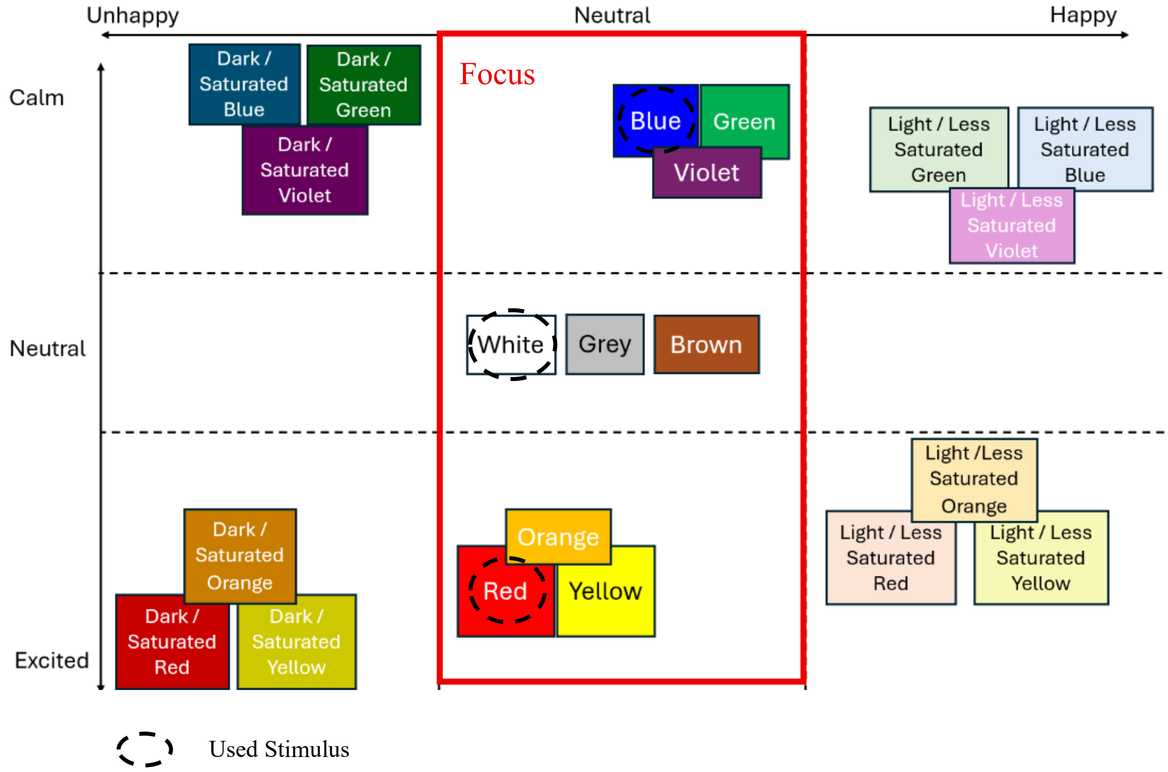
Building ordinances (BNO):

- Gemeinde Arosa (2021): Baugenehmigung der Gemeinde Arosa, Genehmigung 1. September 2021.
- Gemeinde Därstetten (2021): Baureglement der Gemeinde Därstetten, Genehmigung 15. November 2021.
- Gemeinde Engelberg (2025): Baureglement, Genehmigung 7. März 2025
- Gemeinde Fischenthal (2010): Ortsplanung Bau- und Zonenordnung, Genehmigung 14. April 2010.
- Gemeinde Giswil (2020): au- und Zonenreglement, Genehmigung 5. Mai 2020.
- Gemeinde Ins (2021): Revision Ortsplanung, Genehmigung Februar 2021.
- Gemeinde Oberems (2023): Bau- und Zonenreglement, Genehmigung 17 November 2023
- Gemeinde Seengen (2013): Bau- und Nutzungsordnung (BNO), Genehmigung 15. Mai 2013.
- Gemeinde Wäldi (2020): Baureglement, Genehmigung 4. März 2020.
- Gemeinde Walenstadt (2014): Baureglement, Genehmigung 30. April 2014.

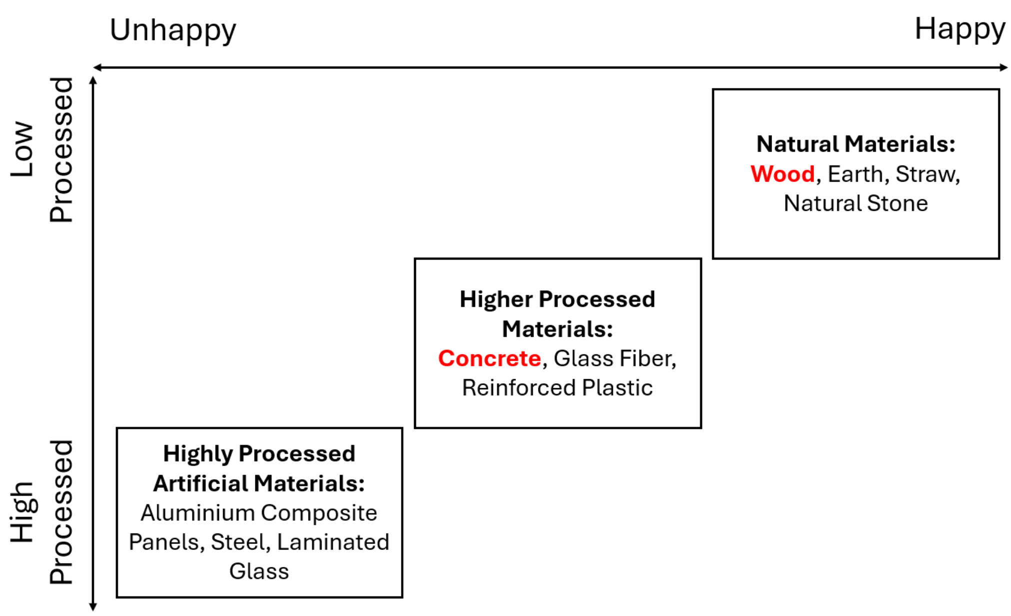
B – List of Assets of the VR–Environment

Asset-Name	Author / Source	Usage in Scene
20 Low Poly House Pack Vol 1&2 Bundle	3D Gallery	Buildings
Chapelle Sainte Anne (35)	Virtualbreizh (FAB)	Buildings
Wooden Door	Surkee (FAB)	Buildings
swissBUILDINGS3D	Swisstopo (Federal Office of Topography, CH)	Background Buil-dings
fenceWood	Esri Canada (City Engine)	Fence-Hedge
Wall8	Esri Canada (City Engine)	Fence-Hedge
hedge	Esri Canada (City Engine)	Fence-Hedge
bench3	Esri Canada (City Engine)	Street Objects
Outdoor Couch Scan MEDPOLY	EFK (FAB)	Street Objects
Outdoor Bench Low-poly	Max3d (FAB)	Street Objects
Outdoor Table Scan MEDPOLY	EFK (FAB)	Street Objects
busStop	Esri Canada (City Engine)	Street Objects
CARLA	Esri Canada (City Engine)	Street Objects
street light	Esri Canada (City Engine)	Street Objects
Garden Swing	Kayozz (FAB)	Street Objects
Bike_Rack	Esri Library (City Engine)	Street Objects
Slide	Esri Library (City Engine)	Street Objects
Streets_Modern_Simple.cga	Esri Library (City Engine)	Streets
European Beech	Quixel (FAB)	Vegetation
Planter Circular	Esri Canada (City Engine)	Vegetation
temperate Vegetation: optimized Grass Li-brary	Project Nature (FAB)	Vegetation
Goldmound Spiraea Red Flowering	HKhalife (FAB)	Vegetation
Phlox Candystrip flower Cluster	HKhalife (FAB)	Vegetation
Acer2	Esri Canada (City Engine)	Vegetation
Yellow coneflowers cluster	HKhalife (FAB)	Vegetation
Bigleaf Hydrangea	Quixel (FAB)	Vegetation
SM_RoadBike	Esri Canada (City Engine)	Vehicles
City_Bike	Esri Library (City Engine)	Vehicles
Lincoln2020	Esri Canada (City Engine)	Vehicles
Prius	Esri Library (City Engine)	Vehicles
Audi A6	Esri Canada (City Engine)	Vehicles
BMW 3 - Series	Esri Library (City Engine)	Vehicles
TexturesCom_TilesPlain0111_1_seem-less_S.png	Esri Canada (City Engine)	Materials - Surfaces
Texture of public street colored tiles	TijerinArt (FAB)	Materials - Surfaces
Texture of public street tiles	TijerinArt (FAB)	Materials – Surfaces
steppe_grass_b.png	Esri Library (City Enigne)	Materials - Surfaces
Wooden Planks	Quixel (FAB)	Materials - Façade
Concrete Façade	Quixel (FAB)	Materials - Façade

C – Color and Material Frameworks



Color framework with focus on hue (red square) and the used color representatives (black circle)

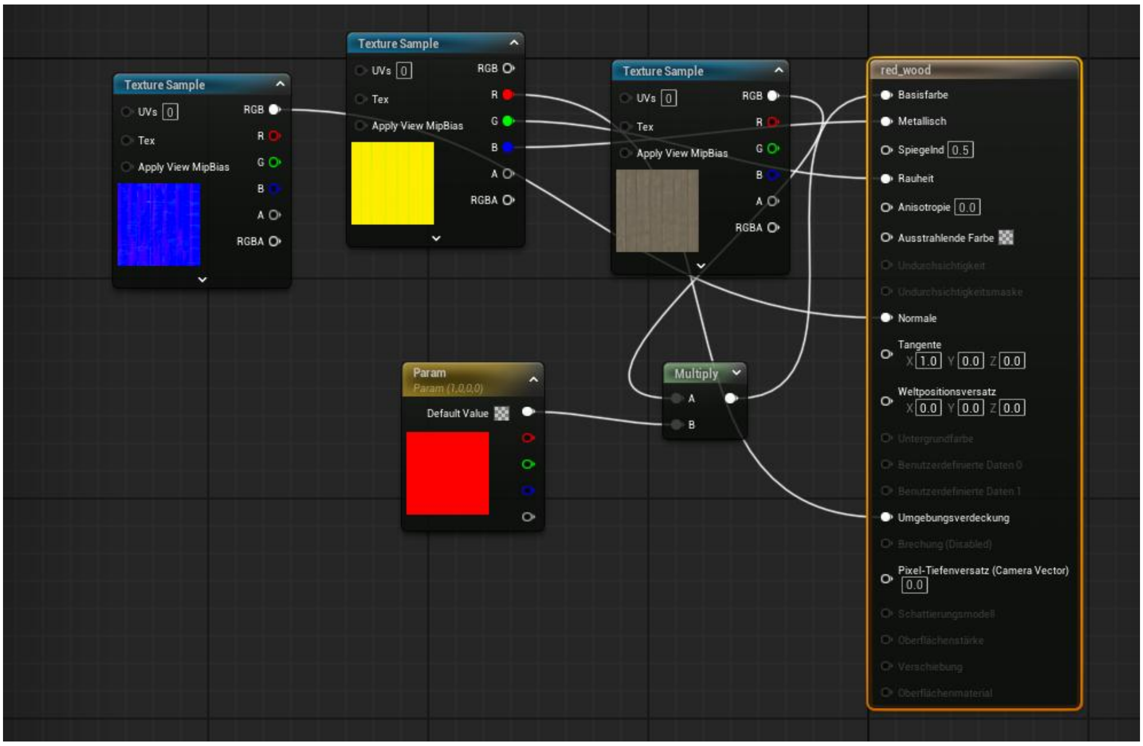


Material framework, used representatives in Red

D – Stimuli Creation in Unreal Engine

Example: Red–Wood

- Texture Sample (gray): wood mask, influencing base color
- Texture Sample (blue) normal map, adds surface detail and depth
- Texture Sample (yellow): ambient occlusion map to emphasize shadowed areas and roughness
- Color Parameter (red): main diffuse color hue adjusted with material instances
- Multiply Node: combined the red color parameter with the wood mask



E – Images of Virtual Reality Environments

Red–Concrete Backyard

Red–Concrete Street

Red–Wood Backyard

Red–Wood Street

Blue–Concrete Backyard

Blue–Concrete Street

Blue–Wood Backyard

Blue–Wood Street

White–Concrete Backyard

White–Concrete Street

White–Wood Backyard

White–Wood Street

F – Template Consent Form (English Version)

Consent Form

Purpose of the Study

Thank you for your interest and participation in my Virtual Reality (VR) study. The aim of this research is to capture and analyze both subjective and measured emotional responses of individuals in virtual rural environments. The study is part of my Master's thesis at the Department of Geography at the University of Zurich and is supervised by Prof. Dr. Sara Irina Fabrikant.

Eligibility Criteria

To participate in this study, the following conditions must be met:

Inclusion Criteria

- Age between 18 and 65 years
- Swiss citizenship or raised in Switzerland

Exclusion Criteria

- Current use of medication affecting the nervous system
- Any form of color vision deficiency (e.g., red-green, blue-yellow deficiency, or achromatopsia)

Procedure

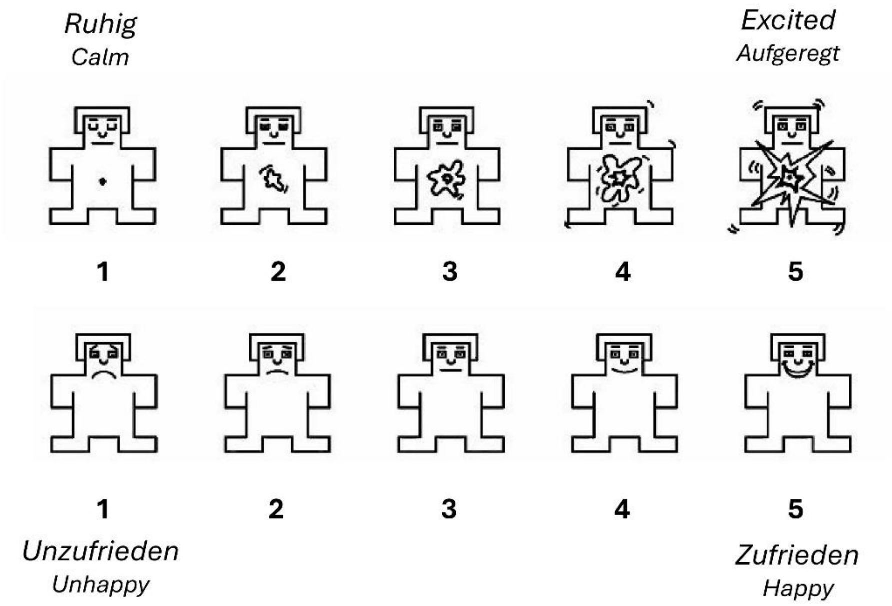
The study will take approximately 45 minutes and will be conducted in May 2025 and June 2025. The procedure is divided into the following parts:

1. Introduction (approx. 10–15 minutes)
2. Virtual Reality experience (exactly 15 minutes)
3. Completion of a questionnaire (approx. 10–15 minutes)

VR Experiment

At the beginning, you will watch a short video. Afterwards, you will explore twelve rural environments in virtual reality. During the experience, you will wear a VR headset and a sensor on your hand to measure electrodermal activity. These devices will remain attached for the entire duration. Each environment will be presented for 30 seconds.

After each scene, you will rate your emotional experience using symbols that appear in the virtual space:



- The **top row** reflects your perceived level of arousal (ranging from calm to excited).
- The **bottom row** reflects your level of satisfaction (ranging from dissatisfied to satisfied).

Please communicate your assessment using two numbers (e.g., “top row: 3, bottom row: 2”).

Potential Risks

The risks associated with this study are considered very low. Participants with no prior VR experience may experience mild dizziness. To minimize this, there is no movement involved during the VR experience — you will remain stationary and only be able to look around. You may withdraw from the study at any time.

Voluntary Participation

Your participation in this study is entirely voluntary. You may withdraw at any time without providing a reason. In the event of withdrawal, any data collected up to that point will not be used.

Data Privacy

Your personal data will be treated strictly confidentially and anonymized. Your name will be replaced with a code and will not appear in any publication. Data will be securely stored and accessible only to the research team.

The following personal data will be collected as part of the study:

- Demographic information
- Electrodermal activity (EDA)

- Assessments of the virtual environments
- Contact details (used solely for coordination purposes)

Contact Information

If you have any questions or concerns about this study, please contact:

- Study lead: Sebastian Quinten (sebastian.quinten@uzh.ch)
- Supervisor: Prof. Dr. Sara Irina Fabrikant (sara.fabrikant@geo.uzh.ch)

Consent Statement

By signing below, I confirm that:

- I have read and understood the information about the study
- I meet the eligibility criteria
- I voluntarily agree to participate and understand I can withdraw at any time without any negative consequences
- I have had sufficient time to decide on my participation
- I agree to the described processing of my data

Signature: ___________________________________

Date: ___________________________________

G – Experimental Workflow

Time	Display	Key + Trigger	Notes
00:00	Baseline Video	Tap	EDA Start
03:00	1. Situation (randomized)	Tap	
03:30	Self Assesment Manikin (SAM)	Tap	
04:00	2. Situation	Tap	
04:30	SAM	Tap	
05:00	3. Situation	Tap	
05:30	SAM	Tap	
06:00	4. Situation	Tap	
06:30	SAM	Tap	
07:00	5. Situation	Tap	
07:30	SAM	Tap	
08:00	6. Situation	Tap	
08:30	SAM	Tap	
09:00	7. Situation	Tap	
09:30	SAM	Tap	
10:00	8. Situation	Tap	
10:30	SAM	Tap	
11:00	9. Situation	Tap	
11:30	SAM	Tap	
12:00	10. Situation	Tap	
12:30	SAM	Tap	
13:00	11. Situation	Tap	
13:30	SAM	Tap	
14:00	12. Situation	Tap	
14:30	SAM	Tap	
15:00	Exit VR	Tap	EDA Stop

H – Template Questionnaire (English Version)

English-US Sebastian

Perception Survey Rural Areas

The following questions are related to the scenes you saw during the VR experiment.

Perceptions of the virtual environment

Please rate your overall impression of the scenes, which was influenced by colors and materials.

How calming did you find the following façade colors in the scenes?

(1 = very calming, 5 = very exciting)

	1	2	3	4	5
red	○	○	○	○	○
blue	○	○	○	○	○
white	○	○	○	○	○

How pleasant did you find the following façade colors in the scenes?

(1 = very unpleasant, 5 = very pleasant)

	1	2	3	4	5
red	○	○	○	○	○
blue	○	○	○	○	○
white	○	○	○	○	○

How calming did you find the following façade materials in the scenes?

(1 = very calming, 5 = very exciting)

	1	2	3	4	5
Wood	○	○	○	○	○
Concrete	○	○	○	○	○

How pleasant did you find the following façade materials in the scenes?

(1 = very unpleasant, 5 = very pleasant)

	1	2	3	4	5
Wood	○	○	○	○	○
Concrete	○	○	○	○	○

To what extent did the specific combination of color and material influence your perception of the scenes depicted?*

- ○ Not at all
- ○ Little
- ○ Medium
- ○ Strong
- ○ Very strong

Which combination of colour and material did you find most pleasant?*

(several answers possible)

- ☐ blue wood
- ☐ blue concrete
- ☐ red wood
- ☐ red concrete
- ☐ white wood
- ☐ white concrete

How pleasant did you find the scene types?

(1 = very unpleasant, 5 = very pleasant)

	1	2	3	4	5
Street scene	○	○	○	○	○
Backyard scene	○	○	○	○	○

Was there a scene that triggered a certain memory or feeling in you? If so, which ones?

(if not, the question can be omitted)

1000

How familiar are you with rural environments in Switzerland?*

(1 = not at all familiar, 5 = very familiar)

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

Where did you grow up?*

- ○ in a city
- ○ in an agglomeration
- ○ in the countryside

Where do you currently live?*

- ○ in a city
- ○ in an agglomeration
- ○ in the countryside

In which region do you live?

Please mark the area on the map. In the upper left corner with + and - you can zoom in and out of the map.
(no specific address necessary, voluntary question)

Esri, USGS | FOEN / Swiss Parks Network, swisstopo, Esri, TomTom, Garmin, FAO, NOAA,… Powered by Esri

General information

How old are you?*

Which gender do you feel you belong to the most?*

- Female
- Male
- Other

"How do you rate your experience with virtual reality?*

- No Experience
- Little Experience
- Moderate Experience
- Enhanced Experience
- Extensive Experience

Would you like to receive a summary of the study results?

If yes, please enter your e-mail address in the field

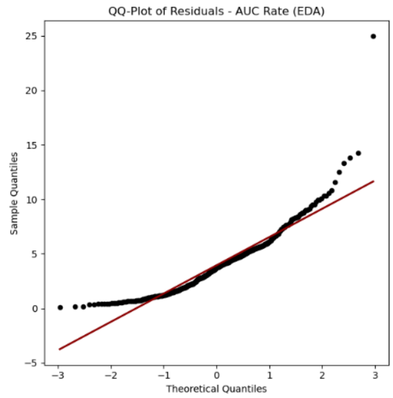
Submit

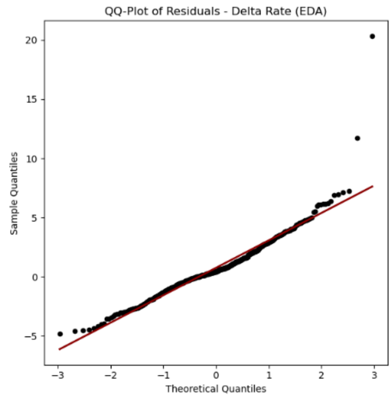
Powered by ArcGIS Survey123

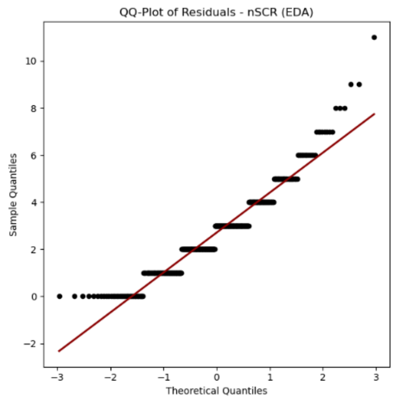
I – Statistical Results

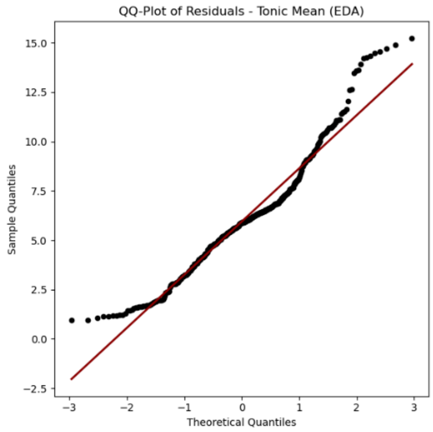
EDA-Data:

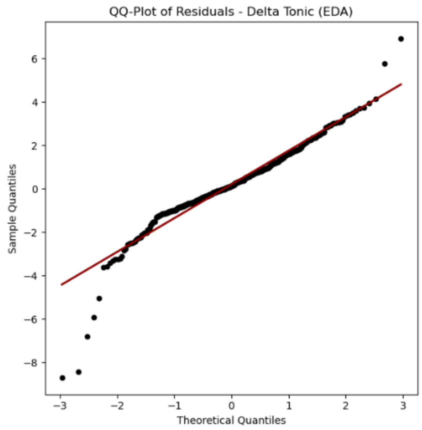
QQ-Plots











Standard derivation (SD)

Standardabweichungen nach Color:

color	AUC_rate	nSCR
blue	2.654	1.988
red	2.565	1.711
white	2.996	1.432

Standardabweichungen nach Material:

material	AUC_rate	nSCR
concrete	2.698	1.774
wood	2.782	1.716

ART ANOVA for metrics

```
=== ANOVA für AUC_rate ===
                         Anova
=====================================================
                        F Value Num DF  Den DF Pr > F
-----------------------------------------------------
color                    0.0621 2.0000 74.0000 0.9399
material                 1.5760 1.0000 37.0000 0.2172
location                 0.0555 1.0000 37.0000 0.8151
color:material           1.4817 2.0000 74.0000 0.2339
color:location           1.8742 2.0000 74.0000 0.1607
material:location        0.0649 1.0000 37.0000 0.8003
color:material:location  3.5149 2.0000 74.0000 0.0348
=====================================================
```

```
=== ANOVA für Delta_rate ===
                         Anova
=====================================================
                        F Value Num DF  Den DF Pr > F
-----------------------------------------------------
color                    0.0621 2.0000 74.0000 0.9399
material                 1.5760 1.0000 37.0000 0.2172
location                 0.0555 1.0000 37.0000 0.8151
color:material           1.4817 2.0000 74.0000 0.2339
color:location           1.8742 2.0000 74.0000 0.1607
material:location        0.0649 1.0000 37.0000 0.8003
color:material:location  3.5149 2.0000 74.0000 0.0348
=====================================================
```

```
=== ANOVA für nSCR ===
                         Anova
=====================================================
                        F Value Num DF  Den DF Pr > F
-----------------------------------------------------
color                    5.2928 2.0000 74.0000 0.0071
material                12.2310 1.0000 37.0000 0.0012
location                 2.5711 1.0000 37.0000 0.1173
color:material           0.0915 2.0000 74.0000 0.9127
color:location           1.6511 2.0000 74.0000 0.1988
material:location        1.1265 1.0000 37.0000 0.2954
color:material:location  8.5611 2.0000 74.0000 0.0005
=====================================================
```

```
=== ANOVA für Tonic_mean ===
                         Anova
=====================================================
                        F Value Num DF  Den DF Pr > F
-----------------------------------------------------
color                    0.2033 2.0000 74.0000 0.8165
material                 0.9815 1.0000 37.0000 0.3283
location                 3.8846 1.0000 37.0000 0.0562
color:material           0.4231 2.0000 74.0000 0.6566
color:location           2.5144 2.0000 74.0000 0.0878
material:location        0.1249 1.0000 37.0000 0.7258
color:material:location  0.5319 2.0000 74.0000 0.5897
=====================================================
```

```
=== ANOVA für Delta_tonic ===
                         Anova
=======================================================
                         F Value Num DF  Den DF Pr > F
-------------------------------------------------------
color                     0.2033 2.0000 74.0000 0.8165
material                  0.9815 1.0000 37.0000 0.3283
location                  3.8846 1.0000 37.0000 0.0562
color:material            0.4231 2.0000 74.0000 0.6566
color:location            2.5144 2.0000 74.0000 0.0878
material:location         0.1249 1.0000 37.0000 0.7258
color:material:location   0.5319 2.0000 74.0000 0.5897
=======================================================
```

Post-hoc Wilcoxon nSCR

```
Post-hoc Wilcoxon (nSCR) - Farben:
         pair     W    p_raw        d    p_adj  significant
  blue vs red 209.0 0.302163 0.116322 0.906488        False
blue vs white 124.5 0.002991 0.515338 0.008974         True
 red vs white 137.5 0.003496 0.502274 0.010489         True

Post-hoc Wilcoxon (nSCR) - Material:
            pair    W   p_raw        d   p_adj  significant
concrete vs wood 92.0 0.00129 0.589406 0.00129         True
```

Three-way interaction post hoc tests

```
      metric  material  location          pair      W     p_raw     p_fdr  \
0   AUC_rate  concrete    street   blue vs red  366.0  0.954284  0.954284
1   AUC_rate  concrete    street blue vs white  348.0  0.752440  0.820844
2   AUC_rate  concrete    street  red vs white  332.0  0.585588  0.812976
3   AUC_rate  concrete  backyard   blue vs red  332.0  0.585588  0.812976
4   AUC_rate  concrete  backyard blue vs white  278.0  0.184292  0.613139
5   AUC_rate  concrete  backyard  red vs white  336.0  0.625738  0.812976
6   AUC_rate      wood    street   blue vs red  328.0  0.546649  0.812976
7   AUC_rate      wood    street blue vs white  295.0  0.280235  0.672564
8   AUC_rate      wood    street  red vs white  341.0  0.677480  0.812976
9   AUC_rate      wood  backyard   blue vs red  282.0  0.204380  0.613139
10  AUC_rate      wood  backyard blue vs white  208.0  0.017571  0.210850
11  AUC_rate      wood  backyard  red vs white  247.0  0.074247  0.445485
12      nSCR  concrete    street   blue vs red  173.0  0.487943  0.532302
13      nSCR  concrete    street blue vs white   85.0  0.002109  0.008437
14      nSCR  concrete    street  red vs white   60.0  0.004830  0.014490
15      nSCR  concrete  backyard   blue vs red  197.5  0.456630  0.532302
16      nSCR  concrete  backyard blue vs white  177.0  0.158081  0.316162
17      nSCR  concrete  backyard  red vs white  163.0  0.351958  0.532302
18      nSCR      wood    street   blue vs red  182.5  0.439245  0.532302
19      nSCR      wood    street blue vs white  177.5  0.777657  0.777657
20      nSCR      wood    street  red vs white  168.5  0.423335  0.532302
21      nSCR      wood  backyard   blue vs red  133.0  0.101021  0.242450
22      nSCR      wood  backyard blue vs white   53.0  0.000537  0.006447
23      nSCR      wood  backyard  red vs white  100.0  0.001672  0.008437
```

	signif_fdr	p_bonf_metric	signif_bonf_metric	cohens_d
0	False	1.000000	False	-0.018460
1	False	1.000000	False	-0.008848
2	False	1.000000	False	0.008873
3	False	1.000000	False	-0.190298
4	False	1.000000	False	-0.205096
5	False	1.000000	False	-0.028465
6	False	1.000000	False	-0.093920
7	False	1.000000	False	-0.174349
8	False	1.000000	False	-0.130569
9	False	1.000000	False	0.252909
10	False	0.210850	False	0.503741
11	False	0.890969	False	0.288186
12	False	1.000000	False	0.038112
13	True	0.025310	True	0.554019
14	True	0.057961	False	0.509558
15	False	1.000000	False	0.099564
16	False	1.000000	False	0.245742
17	False	1.000000	False	0.188167
18	False	1.000000	False	-0.126907
19	False	1.000000	False	0.013578
20	False	1.000000	False	0.154482
21	False	1.000000	False	0.269159
22	True	0.006447	True	0.630462
23	True	0.020064	True	0.568486

Mann–Whitney U for Gender Bias

```
Mann-Whitney U = 146.5, p = 0.5249
Cohen's d = -0.23
```

MN Logit Regression for nSCR with AUC rate

```
                          MNLogit Regression Results
==============================================================================
Dep. Variable:             color_code   No. Observations:                  456
Model:                        MNLogit   Df Residuals:                      450
Method:                           MLE   Df Model:                            4
Date:                Mon, 14 Jul 2025   Pseudo R-squ.:                 0.02621
Time:                        16:40:19   Log-Likelihood:                -487.84
converged:                       True   LL-Null:                       -500.97
Covariance Type:              cluster   LLR p-value:                 2.806e-05
================================================================================
color_code=1       coef    std err          z      P>|z|      [0.025      0.975]
--------------------------------------------------------------------------------
const            0.7181      0.258      2.786      0.005       0.213       1.223
AUC_rate        -0.1724      0.064     -2.690      0.007      -0.298      -0.047
nSCR_c           0.4346      0.105      4.121      0.000       0.228       0.641
--------------------------------------------------------------------------------
color_code=2       coef    std err          z      P>|z|      [0.025      0.975]
--------------------------------------------------------------------------------
const            0.5436      0.200      2.721      0.007       0.152       0.935
AUC_rate        -0.1234      0.046     -2.654      0.008      -0.214      -0.032
nSCR_c           0.3510      0.084      4.165      0.000       0.186       0.516
================================================================================
```

Spatial Background: Kruskal–Wallis

```
Kruskal-Wallis H = 6.200, p = 0.045
```

Spatial Background: Post-hoc Dunn's p values

```
Dunn's p-values (Bonferroni):
                agglomeration      city  countryside
agglomeration       1.000000  0.309355     1.000000
city                0.309355  1.000000     0.040751
countryside         1.000000  0.040751     1.000000
Cohen's d for each pair:
                         pair   d_cohen  p_bonferroni
       agglomeration vs city -0.782951      0.309355
agglomeration vs countryside  0.426184      1.000000
         city vs countryside  1.057884      0.040751
```

Self–Assessment Manikin SAM-Data:

Arousal: Standard Derivation SD

```
material  concrete      wood
color
blue      0.921945  0.847417
red       0.863281  0.902507
white     0.656432  0.702145
```

Arousal: One sided t–tests towards baseline

```
One-sided t-tests for color:
  blue    : t = -11.600, one-sided p = 0.00000, mean = 2.179 (mean < baseline)
  red     : t = -4.110, one-sided p = 0.00003, mean = 2.705 (mean < baseline)
  white   : t = -20.444, one-sided p = 0.00000, mean = 1.891 (mean < baseline)

One-sided t-tests for material:
  concrete: t = -14.366, one-sided p = 0.00000, mean = 2.192 (mean < baseline)
  wood    : t = -11.281, one-sided p = 0.00000, mean = 2.325 (mean < baseline)
```

Arousal: Three-factor Type II ANOVA

```
=== Dreifaktorielle ANOVA (Typ II) ===
                                      sum_sq     df          F        PR(>F)
C(color)                           53.158120    2.0  39.601374  1.386130e-16
C(material)                         2.053419    1.0   3.059484  8.093994e-02
C(location)                         4.720085    1.0   7.032674  8.282470e-03
C(color):C(material)                2.517094    2.0   1.875168  1.545097e-01
C(color):C(location)                0.517094    2.0   0.385221  6.805213e-01
C(material):C(location)             0.053419    1.0   0.079591  7.779802e-01
C(color):C(material):C(location)    0.645299    2.0   0.480731  6.186445e-01
Residual                          306.051282  456.0        NaN           NaN
```

Arousal: Post hoc Turkey HSD test

```
--- Tukey HSD für color ---
Multiple Comparison of Means - Tukey HSD, FWER=0.05
===================================================
group1 group2 meandiff p-adj  lower   upper  reject
---------------------------------------------------
  blue    red   0.5256   0.0   0.306  0.7453   True
  blue  white  -0.2885 0.006 -0.5081 -0.0688   True
   red  white  -0.8141   0.0 -1.0338 -0.5944   True
---------------------------------------------------

Cohen's d für Paarvergleiche:
  blue vs red: d = -0.591
  blue vs white: d = 0.366
  red vs white: d = 1.025

--- Tukey HSD für material ---
 Multiple Comparison of Means - Tukey HSD, FWER=0.05
=====================================================
 group1  group2 meandiff p-adj   lower  upper  reject
-----------------------------------------------------
concrete   wood   0.1325 0.1074 -0.0289 0.2938  False
-----------------------------------------------------

Cohen's d für Paarvergleiche:
  concrete vs wood: d = -0.149

 --- Tukey HSD für location ---
 Multiple Comparison of Means - Tukey HSD, FWER=0.05
 ===================================================
  group1  group2 meandiff p-adj  lower  upper  reject
 ---------------------------------------------------
 backyard street   0.2009 0.0145 0.0401 0.3616   True
 ---------------------------------------------------

 Cohen's d für Paarvergleiche:
   street vs backyard: d = 0.227

 === Tukey HSD für alle Situationen ===
                     Multiple Comparison of Means - Tukey HSD, FWER=0.05
 ===========================================================================================
           group1                      group2           meandiff p-adj   lower   upper  reject
 -------------------------------------------------------------------------------------------
     1 (blue concrete street) 10 (white concrete backyard)  -0.4872 0.2683 -1.0967  0.1223  False
     1 (blue concrete street)      11 (white wood street)  -0.2051 0.9944 -0.8146  0.4043  False
     1 (blue concrete street)    12 (white wood backyard)  -0.5385 0.1435 -1.1479   0.071  False
     1 (blue concrete street)   2 (blue concrete backyard)  -0.2308 0.9851 -0.8402  0.3787  False
     1 (blue concrete street)         3 (blue wood street)      0.0    1.0 -0.6095  0.6095  False
     1 (blue concrete street)       4 (blue wood backyard)  -0.0769    1.0 -0.6864  0.5326  False
     1 (blue concrete street)      5 (red concrete street)   0.3077 0.8858 -0.3018  0.9172  False
     1 (blue concrete street)    6 (red concrete backyard)   0.2564 0.9665 -0.3531  0.8659  False
     1 (blue concrete street)          7 (red wood street)   0.7436 0.0041  0.1341  1.3531   True
     1 (blue concrete street)        8 (red wood backyard)   0.4872 0.2683 -0.1223  1.0967  False
     1 (blue concrete street)    9 (white concrete street)  -0.2308 0.9851 -0.8402  0.3787  False
 10 (white concrete backyard)      11 (white wood street)   0.2821 0.9345 -0.3274  0.8915  False
 10 (white concrete backyard)    12 (white wood backyard)  -0.0513    1.0 -0.6608  0.5582  False
 10 (white concrete backyard)   2 (blue concrete backyard)   0.2564 0.9665 -0.3531  0.8659  False
 10 (white concrete backyard)         3 (blue wood street)   0.4872 0.2683 -0.1223  1.0967  False
 10 (white concrete backyard)       4 (blue wood backyard)   0.4103 0.5422 -0.1992  1.0197  False
 10 (white concrete backyard)      5 (red concrete street)   0.7949 0.0013  0.1854  1.4043   True
 10 (white concrete backyard)    6 (red concrete backyard)   0.7436 0.0041  0.1341  1.3531   True
 10 (white concrete backyard)          7 (red wood street)   1.2308    0.0  0.6213  1.8402   True
 10 (white concrete backyard)        8 (red wood backyard)   0.9744    0.0  0.3649  1.5838   True
 10 (white concrete backyard)    9 (white concrete street)   0.2564 0.9665 -0.3531  0.8659  False
       11 (white wood street)    12 (white wood backyard)  -0.3333 0.8193 -0.9428  0.2761  False
       11 (white wood street)   2 (blue concrete backyard)  -0.0256    1.0 -0.6351  0.5838  False
       11 (white wood street)         3 (blue wood street)   0.2051 0.9944 -0.4043  0.8146  False
       11 (white wood street)       4 (blue wood backyard)   0.1282 0.9999 -0.4813  0.7377  False
```

11 (white wood street)	5 (red concrete street)	0.5128	0.1992	-0.0967	1.1223	False
11 (white wood street)	6 (red concrete backyard)	0.4615	0.3503	-0.1479	1.071	False
11 (white wood street)	7 (red wood street)	0.9487	0.0	0.3392	1.5582	True
11 (white wood street)	8 (red wood backyard)	0.6923	0.0114	0.0828	1.3018	True
11 (white wood street)	9 (white concrete street)	-0.0256	1.0	-0.6351	0.5838	False
12 (white wood backyard)	2 (blue concrete backyard)	0.3077	0.8858	-0.3018	0.9172	False
12 (white wood backyard)	3 (blue wood street)	0.5385	0.1435	-0.071	1.1479	False
12 (white wood backyard)	4 (blue wood backyard)	0.4615	0.3503	-0.1479	1.071	False
12 (white wood backyard)	5 (red concrete street)	0.8462	0.0004	0.2367	1.4556	True
12 (white wood backyard)	6 (red concrete backyard)	0.7949	0.0013	0.1854	1.4043	True
12 (white wood backyard)	7 (red wood street)	1.2821	0.0	0.6726	1.8915	True
12 (white wood backyard)	8 (red wood backyard)	1.0256	0.0	0.4162	1.6351	True
12 (white wood backyard)	9 (white concrete street)	0.3077	0.8858	-0.3018	0.9172	False
2 (blue concrete backyard)	3 (blue wood street)	0.2308	0.9851	-0.3787	0.8402	False
2 (blue concrete backyard)	4 (blue wood backyard)	0.1538	0.9996	-0.4556	0.7633	False
2 (blue concrete backyard)	5 (red concrete street)	0.5385	0.1435	-0.071	1.1479	False
2 (blue concrete backyard)	6 (red concrete backyard)	0.4872	0.2683	-0.1223	1.0967	False
2 (blue concrete backyard)	7 (red wood street)	0.9744	0.0	0.3649	1.5838	True
2 (blue concrete backyard)	8 (red wood backyard)	0.7179	0.0069	0.1085	1.3274	True
2 (blue concrete backyard)	9 (white concrete street)	0.0	1.0	-0.6095	0.6095	False
3 (blue wood street)	4 (blue wood backyard)	-0.0769	1.0	-0.6864	0.5326	False
3 (blue wood street)	5 (red concrete street)	0.3077	0.8858	-0.3018	0.9172	False
3 (blue wood street)	6 (red concrete backyard)	0.2564	0.9665	-0.3531	0.8659	False
3 (blue wood street)	7 (red wood street)	0.7436	0.0041	0.1341	1.3531	True
3 (blue wood street)	8 (red wood backyard)	0.4872	0.2683	-0.1223	1.0967	False
3 (blue wood street)	9 (white concrete street)	-0.2308	0.9851	-0.8402	0.3787	False
4 (blue wood backyard)	5 (red concrete street)	0.3846	0.6423	-0.2249	0.9941	False
4 (blue wood backyard)	6 (red concrete backyard)	0.3333	0.8193	-0.2761	0.9428	False
4 (blue wood backyard)	7 (red wood street)	0.8205	0.0007	0.211	1.43	True
4 (blue wood backyard)	8 (red wood backyard)	0.5641	0.1005	-0.0454	1.1736	False
4 (blue wood backyard)	9 (white concrete street)	-0.1538	0.9996	-0.7633	0.4556	False
5 (red concrete street)	6 (red concrete backyard)	-0.0513	1.0	-0.6608	0.5582	False
5 (red concrete street)	7 (red wood street)	0.4359	0.443	-0.1736	1.0454	False
5 (red concrete street)	8 (red wood backyard)	0.1795	0.9983	-0.43	0.789	False
5 (red concrete street)	9 (white concrete street)	-0.5385	0.1435	-1.1479	0.071	False
6 (red concrete backyard)	7 (red wood street)	0.4872	0.2683	-0.1223	1.0967	False
6 (red concrete backyard)	8 (red wood backyard)	0.2308	0.9851	-0.3787	0.8402	False
6 (red concrete backyard)	9 (white concrete street)	-0.4872	0.2683	-1.0967	0.1223	False
7 (red wood street)	8 (red wood backyard)	-0.2564	0.9665	-0.8659	0.3531	False
7 (red wood street)	9 (white concrete street)	-0.9744	0.0	-1.5838	-0.3649	True
8 (red wood backyard)	9 (white concrete street)	-0.7179	0.0069	-1.3274	-0.1085	True

Arousal: Paired t–test Color x Material – Red

```
Paired t-test (Red: concrete vs. wood): t = -6.205, p = 0.00000002546499290890
Cohen's dz = -0.70255942
```

Arousal: Welch t–test – Gender

	Group	Male_mean	Female_mean	t_stat	p_value
0	Color=blue	2.230769	2.120000	0.783892	0.434587
1	Color=red	2.616667	2.730000	-0.808579	0.420133
2	Color=white	1.857143	1.910000	-0.468365	0.640406
3	Material=concrete	2.204545	2.180000	0.225335	0.821936
4	Material=wood	2.287500	2.326667	-0.314539	0.753492

Valence: Standard Derivation

material	concrete	wood
color		
blue	0.900013	0.900013
red	0.942309	1.030665
white	1.002162	0.847711

Valence: One-sided t–tests

```
One-sided t-tests for color (Valence):
  blue    : t = 3.391, one-sided p = 0.00044, mean = 3.244 (mean > baseline)
  red     : t = 1.207, one-sided p = 0.11471, mean = 3.096 (mean > baseline)
  white   : t = 4.500, one-sided p = 0.00001, mean = 3.333 (mean > baseline)

One-sided t-tests for material (Valence):
  concrete: t = 4.423, one-sided p = 0.00001, mean = 3.274 (mean > baseline)
  wood    : t = 2.852, one-sided p = 0.00237, mean = 3.175 (mean > baseline)
```

Valence: Three-factor Type II ANOVA

```
=== Dreifaktorielle ANOVA (Typ II) ===
                                     sum_sq     df          F        PR(>F)
C(color)                          53.158120    2.0  39.601374  1.386130e-16
C(material)                        2.053419    1.0   3.059484  8.093994e-02
C(location)                        4.720085    1.0   7.032674  8.282470e-03
C(color):C(material)               2.517094    2.0   1.875168  1.545097e-01
C(color):C(location)               0.517094    2.0   0.385221  6.805213e-01
C(material):C(location)            0.053419    1.0   0.079591  7.779802e-01
C(color):C(material):C(location)   0.645299    2.0   0.480731  6.186445e-01
Residual                         306.051282  456.0        NaN           NaN
```

Valence: Post-hoc Turkey HSD

```
--- Tukey HSD für color (Valence) ---
Multiple Comparison of Means - Tukey HSD, FWER=0.05
===================================================
group1 group2 meandiff p-adj   lower  upper  reject
---------------------------------------------------
  blue    red  -0.1474 0.3495 -0.3977 0.1028  False
  blue  white   0.0897 0.6764 -0.1605   0.34  False
   red  white   0.2372 0.0676 -0.0131 0.4875  False
---------------------------------------------------

Cohen's d für Paarvergleiche (Valence):
  blue vs red: d = 0.156
  blue vs white: d = -0.098
  red vs white: d = -0.247

--- Tukey HSD für material (Valence) ---
Multiple Comparison of Means - Tukey HSD, FWER=0.05
====================================================
 group1  group2 meandiff p-adj   lower  upper reject
----------------------------------------------------
concrete   wood  -0.0983 0.2601 -0.2696 0.073  False
----------------------------------------------------

Cohen's d für Paarvergleiche (Valence):
  concrete vs wood: d = 0.104

--- Tukey HSD für location (Valence) ---
 Multiple Comparison of Means - Tukey HSD, FWER=0.05
=====================================================
 group1  group2 meandiff p-adj  lower   upper  reject
-----------------------------------------------------
backyard street  -0.4316   0.0 -0.5986 -0.2647   True
-----------------------------------------------------

Cohen's d für Paarvergleiche (Valence):
  street vs backyard: d = -0.470
```

=== Tukey HSD für alle Situationen (Valence) ===

Multiple Comparison of Means - Tukey HSD, FWER=0.05

group1	group2	meandiff	p-adj	lower	upper	reject
1 (blue concrete street)	10 (white concrete backyard)	0.7179	0.0285	0.0372	1.3987	True
1 (blue concrete street)	11 (white wood street)	0.0769	1.0	-0.6039	0.7577	False
1 (blue concrete street)	12 (white wood backyard)	0.5897	0.1647	-0.091	1.2705	False
1 (blue concrete street)	2 (blue concrete backyard)	0.4872	0.442	-0.1936	1.168	False
1 (blue concrete street)	3 (blue wood street)	0.1282	1.0	-0.5526	0.809	False
1 (blue concrete street)	4 (blue wood backyard)	0.359	0.8524	-0.3218	1.0397	False
1 (blue concrete street)	5 (red concrete street)	0.1026	1.0	-0.5782	0.7833	False
1 (blue concrete street)	6 (red concrete backyard)	0.3846	0.7856	-0.2962	1.0654	False
1 (blue concrete street)	7 (red wood street)	-0.2051	0.9979	-0.8859	0.4756	False
1 (blue concrete street)	8 (red wood backyard)	0.1026	1.0	-0.5782	0.7833	False
1 (blue concrete street)	9 (white concrete street)	-0.0513	1.0	-0.7321	0.6295	False
10 (white concrete backyard)	11 (white wood street)	-0.641	0.087	-1.3218	0.0397	False
10 (white concrete backyard)	12 (white wood backyard)	-0.1282	1.0	-0.809	0.5526	False
10 (white concrete backyard)	2 (blue concrete backyard)	-0.2308	0.994	-0.9115	0.45	False
10 (white concrete backyard)	3 (blue wood street)	-0.5897	0.1647	-1.2705	0.091	False
10 (white concrete backyard)	4 (blue wood backyard)	-0.359	0.8524	-1.0397	0.3218	False
10 (white concrete backyard)	5 (red concrete street)	-0.6154	0.1211	-1.2962	0.0654	False
10 (white concrete backyard)	6 (red concrete backyard)	-0.3333	0.9054	-1.0141	0.3474	False
10 (white concrete backyard)	7 (red wood street)	-0.9231	0.0006	-1.6039	-0.2423	True
10 (white concrete backyard)	8 (red wood backyard)	-0.6154	0.1211	-1.2962	0.0654	False
10 (white concrete backyard)	9 (white concrete street)	-0.7692	0.0123	-1.45	-0.0885	True
11 (white wood street)	12 (white wood backyard)	0.5128	0.3587	-0.168	1.1936	False
11 (white wood street)	2 (blue concrete backyard)	0.4103	0.7071	-0.2705	1.091	False
11 (white wood street)	3 (blue wood street)	0.0513	1.0	-0.6295	0.7321	False
11 (white wood street)	4 (blue wood backyard)	0.2821	0.9701	-0.3987	0.9628	False
11 (white wood street)	5 (red concrete street)	0.0256	1.0	-0.6551	0.7064	False
11 (white wood street)	6 (red concrete backyard)	0.3077	0.9442	-0.3731	0.9885	False
11 (white wood street)	7 (red wood street)	-0.2821	0.9701	-0.9628	0.3987	False
11 (white wood street)	8 (red wood backyard)	0.0256	1.0	-0.6551	0.7064	False
11 (white wood street)	9 (white concrete street)	-0.1282	1.0	-0.809	0.5526	False
12 (white wood backyard)	2 (blue concrete backyard)	-0.1026	1.0	-0.7833	0.5782	False
12 (white wood backyard)	3 (blue wood street)	-0.4615	0.5307	-1.1423	0.2192	False
12 (white wood backyard)	4 (blue wood backyard)	-0.2308	0.994	-0.9115	0.45	False
12 (white wood backyard)	5 (red concrete street)	-0.4872	0.442	-1.168	0.1936	False
12 (white wood backyard)	6 (red concrete backyard)	-0.2051	0.9979	-0.8859	0.4756	False
12 (white wood backyard)	7 (red wood street)	-0.7949	0.0078	-1.4756	-0.1141	True
12 (white wood backyard)	8 (red wood backyard)	-0.4872	0.442	-1.168	0.1936	False
12 (white wood backyard)	9 (white concrete street)	-0.641	0.087	-1.3218	0.0397	False
2 (blue concrete backyard)	3 (blue wood street)	-0.359	0.8524	-1.0397	0.3218	False
2 (blue concrete backyard)	4 (blue wood backyard)	-0.1282	1.0	-0.809	0.5526	False
2 (blue concrete backyard)	5 (red concrete street)	-0.3846	0.7856	-1.0654	0.2962	False
2 (blue concrete backyard)	6 (red concrete backyard)	-0.1026	1.0	-0.7833	0.5782	False
2 (blue concrete backyard)	7 (red wood street)	-0.6923	0.0422	-1.3731	-0.0115	True
2 (blue concrete backyard)	8 (red wood backyard)	-0.3846	0.7856	-1.0654	0.2962	False
2 (blue concrete backyard)	9 (white concrete street)	-0.5385	0.2836	-1.2192	0.1423	False
3 (blue wood street)	4 (blue wood backyard)	0.2308	0.994	-0.45	0.9115	False
3 (blue wood street)	5 (red concrete street)	-0.0256	1.0	-0.7064	0.6551	False
3 (blue wood street)	6 (red concrete backyard)	0.2564	0.9857	-0.4244	0.9372	False
3 (blue wood street)	7 (red wood street)	-0.3333	0.9054	-1.0141	0.3474	False
3 (blue wood street)	8 (red wood backyard)	-0.0256	1.0	-0.7064	0.6551	False
3 (blue wood street)	9 (white concrete street)	-0.1795	0.9994	-0.8603	0.5013	False
4 (blue wood backyard)	5 (red concrete street)	-0.2564	0.9857	-0.9372	0.4244	False
4 (blue wood backyard)	6 (red concrete backyard)	0.0256	1.0	-0.6551	0.7064	False
4 (blue wood backyard)	7 (red wood street)	-0.5641	0.2187	-1.2449	0.1167	False
4 (blue wood backyard)	8 (red wood backyard)	-0.2564	0.9857	-0.9372	0.4244	False
4 (blue wood backyard)	9 (white concrete street)	-0.4103	0.7071	-1.091	0.2705	False
5 (red concrete street)	6 (red concrete backyard)	0.2821	0.9701	-0.3987	0.9628	False
5 (red concrete street)	7 (red wood street)	-0.3077	0.9442	-0.9885	0.3731	False
5 (red concrete street)	8 (red wood backyard)	0.0	1.0	-0.6808	0.6808	False
5 (red concrete street)	9 (white concrete street)	-0.1538	0.9999	-0.8346	0.5269	False
6 (red concrete backyard)	7 (red wood street)	-0.5897	0.1647	-1.2705	0.091	False
6 (red concrete backyard)	8 (red wood backyard)	-0.2821	0.9701	-0.9628	0.3987	False
6 (red concrete backyard)	9 (white concrete street)	-0.4359	0.6206	-1.1167	0.2449	False
7 (red wood street)	8 (red wood backyard)	0.3077	0.9442	-0.3731	0.9885	False
7 (red wood street)	9 (white concrete street)	0.1538	0.9999	-0.5269	0.8346	False
8 (red wood backyard)	9 (white concrete street)	-0.1538	0.9999	-0.8346	0.5269	False

Valence: Paired t–test Color x Material – Red

```
Paired t-test (Red Valence: concrete vs. wood): t = 5.675, p = 0.00000023361154456188
Cohen's dz (Valence) = 0.64251110
```

Valence: Welch t–tests – Gender

	Group	Male_mean	Female_mean	t_stat	p_value
0	Color=blue	2.230769	2.120000	0.783892	0.434587
1	Color=red	2.616667	2.730000	-0.808579	0.420133
2	Color=white	1.857143	1.910000	-0.468365	0.640406
3	Material=concrete	2.204545	2.180000	0.225335	0.821936
4	Material=wood	2.287500	2.326667	-0.314539	0.753492

Valence: ANOVA Type II with Gender

	sum_sq	df	F	PR(>F)
C(Color)	4.474359	2.0	2.544351	0.079638
C(Material)	1.130342	1.0	1.285541	0.257467
C(Gender)	5.212308	1.0	5.927973	0.015285
C(Color):C(Material)	2.260684	2.0	1.285541	0.277501
C(Color):C(Gender)	0.981355	2.0	0.558049	0.572715
C(Material):C(Gender)	0.047277	1.0	0.053768	0.816735
C(Color):C(Material):C(Gender)	0.387411	2.0	0.220302	0.802362
Residual	400.948571	456.0	NaN	NaN

Spatial Background: One-sided t–tests

```
-- Arousal by Color & Environment --

[City]
Blue      N=44  t=-4.73  p(>3)=1.000  p(<3)=0.000
Red       N=44  t=-7.83  p(>3)=1.000  p(<3)=0.000
White     N=44  t=-4.37  p(>3)=1.000  p(<3)=0.000

[Agglo]
Blue      N=48  t=-6.76  p(>3)=1.000  p(<3)=0.000
Red       N=48  t=-5.86  p(>3)=1.000  p(<3)=0.000
White     N=48  t=-5.46  p(>3)=1.000  p(<3)=0.000

[Land]
Blue      N=64  t=-8.68  p(>3)=1.000  p(<3)=0.000
Red       N=64  t=-6.76  p(>3)=1.000  p(<3)=0.000
White     N=64  t=-4.59  p(>3)=1.000  p(<3)=0.000

-- Arousal by Material & Environment --

[City]
Concrete  N=66  t=-6.06  p(>3)=1.000  p(<3)=0.000
Wood      N=66  t=-7.41  p(>3)=1.000  p(<3)=0.000

[Agglo]
Concrete  N=72  t=-8.07  p(>3)=1.000  p(<3)=0.000
Wood      N=72  t=-6.78  p(>3)=1.000  p(<3)=0.000

[Land]
Concrete  N=96  t=-7.94  p(>3)=1.000  p(<3)=0.000
Wood      N=96  t=-7.77  p(>3)=1.000  p(<3)=0.000
```

```
-- Valence by Color & Environment --

[City]
Blue      N=44  t=1.18  p(>3)=0.122  p(<3)=0.878
Red       N=44  t=0.35  p(>3)=0.364  p(<3)=0.636
White     N=44  t=2.55  p(>3)=0.007  p(<3)=0.993

[Agglo]
Blue      N=48  t=2.87  p(>3)=0.003  p(<3)=0.997
Red       N=48  t=1.37  p(>3)=0.088  p(<3)=0.912
White     N=48  t=0.29  p(>3)=0.388  p(<3)=0.612

[Land]
Blue      N=64  t=5.09  p(>3)=0.000  p(<3)=1.000
Red       N=64  t=0.75  p(>3)=0.229  p(<3)=0.771
White     N=64  t=1.32  p(>3)=0.096  p(<3)=0.904

-- Valence by Material & Environment --

[City]
Concrete  N=66  t=1.13  p(>3)=0.131  p(<3)=0.869
Wood      N=66  t=2.25  p(>3)=0.014  p(<3)=0.986

[Agglo]
Concrete  N=72  t=3.41  p(>3)=0.001  p(<3)=0.999
Wood      N=72  t=0.34  p(>3)=0.366  p(<3)=0.634

[Land]
Concrete  N=96  t=3.35  p(>3)=0.001  p(<3)=0.999
Wood      N=96  t=2.05  p(>3)=0.022  p(<3)=0.978
```

Spatial Background: MixedLM

```
=== MixedLM for Arousal (Additive Model) ===
                            Mixed Linear Model Regression Results
============================================================================================
Model:                         MixedLM            Dependent Variable:             Arousal
No. Observations:              468                Method:                         REML
No. Groups:                    39                 Scale:                          0.6022
Min. group size:               12                 Log-Likelihood:                 -581.9914
Max. group size:               12                 Converged:                      Yes
Mean group size:               12.0
--------------------------------------------------------------------------------------------
                                                   Coef.  Std.Err.   z    P>|z| [0.025 0.975]
--------------------------------------------------------------------------------------------
Intercept                                          2.332    0.158 14.750 0.000  2.022  2.642
C(Environment, Treatment(reference='Agglo'))[T.City]  0.072    0.210  0.342 0.732 -0.340  0.484
C(Environment, Treatment(reference='Agglo'))[T.Land]  0.073    0.192  0.379 0.705 -0.304  0.450
C(Color, Treatment(reference='White'))[T.Blue]      -0.173    0.088 -1.970 0.049 -0.345 -0.001
C(Color, Treatment(reference='White'))[T.Red]       -0.167    0.088 -1.897 0.058 -0.339  0.006
C(Material, Treatment(reference='Concrete'))[T.Wood] -0.021    0.072 -0.298 0.766 -0.162  0.119
Group Var                                          0.204    0.080
============================================================================================

=== MixedLM for Valence (Additive Model) ===
                            Mixed Linear Model Regression Results
============================================================================================
Model:                         MixedLM            Dependent Variable:             Valence
No. Observations:              468                Method:                         REML
No. Groups:                    39                 Scale:                          0.6649
Min. group size:               12                 Log-Likelihood:                 -605.2235
Max. group size:               12                 Converged:                      Yes
Mean group size:               12.0
--------------------------------------------------------------------------------------------
                                                   Coef.  Std.Err.   z    P>|z| [0.025 0.975]
--------------------------------------------------------------------------------------------
Intercept                                          3.237    0.167 19.331 0.000  2.909  3.565
C(Environment, Treatment(reference='Agglo'))[T.City] -0.048    0.223 -0.215 0.830 -0.485  0.389
C(Environment, Treatment(reference='Agglo'))[T.Land]  0.038    0.204  0.187 0.851 -0.362  0.438
C(Color, Treatment(reference='White'))[T.Blue]       0.212    0.092  2.291 0.022  0.031  0.393
C(Color, Treatment(reference='White'))[T.Red]       -0.058    0.092 -0.625 0.532 -0.239  0.123
C(Material, Treatment(reference='Concrete'))[T.Wood] -0.132    0.075 -1.757 0.079 -0.280  0.015
Group Var                                          0.230    0.086
============================================================================================
```

Spatial Background: Post-hoc pairwise comparisons

```
=== Post-hoc Environment effects for Arousal by Color ===
Blue: Agglo vs City: t=-1.18, p=0.241, d=-0.25
Blue: Agglo vs Land: t=0.13, p=0.898, d=0.02
Blue: City vs Land: t=1.42, p=0.159, d=0.28
Red: Agglo vs City: t=0.65, p=0.515, d=0.14
Red: Agglo vs Land: t=-0.73, p=0.469, d=-0.14
Red: City vs Land: t=-1.56, p=0.122, d=-0.30
White: Agglo vs City: t=-0.63, p=0.532, d=-0.13
White: Agglo vs Land: t=-0.63, p=0.533, d=-0.12
White: City vs Land: t=0.02, p=0.988, d=0.00

=== Post-hoc Environment effects for Arousal by Material ===
Concrete: Agglo vs City: t=-1.25, p=0.212, d=-0.21
Concrete: Agglo vs Land: t=-0.66, p=0.511, d=-0.10
Concrete: City vs Land: t=0.67, p=0.507, d=0.11
Wood: Agglo vs City: t=0.25, p=0.803, d=0.04
Wood: Agglo vs Land: t=-0.38, p=0.702, d=-0.06
Wood: City vs Land: t=-0.67, p=0.505, d=-0.11

=== Post-hoc Environment effects for Valence by Color ===
Blue: Agglo vs City: t=1.51, p=0.135, d=0.31
Blue: Agglo vs Land: t=-0.64, p=0.524, d=-0.13
Blue: City vs Land: t=-2.54, p=0.013, d=-0.49
Red: Agglo vs City: t=0.82, p=0.417, d=0.17
Red: Agglo vs Land: t=0.58, p=0.562, d=0.11
Red: City vs Land: t=-0.27, p=0.790, d=-0.05
White: Agglo vs City: t=-1.51, p=0.134, d=-0.31
White: Agglo vs Land: t=-0.61, p=0.543, d=-0.12
White: City vs Land: t=1.03, p=0.304, d=0.20

=== Post-hoc Environment effects for Valence by Material ===
Concrete: Agglo vs City: t=1.77, p=0.079, d=0.30
Concrete: Agglo vs Land: t=0.52, p=0.601, d=0.08
Concrete: City vs Land: t=-1.40, p=0.164, d=-0.22
Wood: Agglo vs City: t=-1.18, p=0.241, d=-0.20
Wood: Agglo vs Land: t=-1.01, p=0.315, d=-0.16
Wood: City vs Land: t=0.21, p=0.834, d=0.03
```

Questionnaire-Data:

Testing Normality –Shapiro-Wilk Test

	Condition	W	p-value
0	Rot Arousal	0.9113	0.0047
1	Blau Arousal	0.8489	0.0001
2	Weiss Arousal	0.8618	0.0002
3	Rot Valence	0.9008	0.0023
4	Blau Valence	0.8896	0.0011
5	Weiss Valence	0.8832	0.0008
6	Holz Arousal	0.8806	0.0006
7	Beton Arousal	0.8504	0.0001
8	Holz Valence	0.8710	0.0004
9	Beton Valence	0.8982	0.0020

Standard Derivation SD

```
Standardabweichungen Arousal - Color:
Blue: SD = 1.03
White: SD = 1.03
Red: SD = 1.26

Standardabweichungen Valence - Color:
Blue: SD = 1.21
White: SD = 1.05
Red: SD = 1.35

Standardabweichungen Arousal - Material:
Wood: SD = 0.96
Concrete: SD = 0.76

Standardabweichungen Valence - Material:
Wood: SD = 0.94
Concrete: SD = 1.13
```

Wilcoxon against baseline

```
=== One-sample Wilcoxon vs. 3 — Farben (Arousal) ===
Rot    → W=172.00, p_one-sided=0.846
Blau   → W=175.50, p_one-sided=0.899
Weiss  → W=53.50, p_one-sided=1.000

=== One-sample Wilcoxon vs. 3 — Materialien (Arousal) ===
Holz   → W=88.00, p_one-sided=0.991
Beton  → W=28.50, p_one-sided=0.999

=== One-sample Wilcoxon vs. 3 — Farben (Arousal), less (unter 3) ===
Rot    → W=172.00, p_one-sided(less)=0.84612
Blau   → W=175.50, p_one-sided(less)=0.89894
Weiss  → W=53.50, p_one-sided(less)=0.00004

=== One-sample Wilcoxon vs. 3 — Materialien (Arousal), less (unter 3) ===
Holz   → W=88.00, p_one-sided(less)=0.99127
Beton  → W=28.50, p_one-sided(less)=0.99947

=== One-sample Wilcoxon vs. 3 — Farben (Valence), greater ===
Rot    → W=226.00, p_one-sided(greater)=0.672
Blau   → W=127.50, p_one-sided(greater)=0.629
Weiss  → W=115.50, p_one-sided(greater)=0.003

=== One-sample Wilcoxon vs. 3 — Farben (Valence), less ===
Rot    → W=226.00, p_one-sided(less)=0.672
Blau   → W=127.50, p_one-sided(less)=0.629
Weiss  → W=115.50, p_one-sided(less)=0.997

=== One-sample Wilcoxon vs. 3 — Materialien (Valence) ===
Holz   → W=72.00, p_one-sided(greater)=0.00040, p_one-sided(less)=1.000
Beton  → W=142.00, p_one-sided(greater)=0.71753, p_one-sided(less)=0.718
```

Arousal & Valence: Friedmann & Post–hoc Wilcoxon – Color

```
Friedman Arousal (Rot/Blau/Weiss): χ²=13.419, p=0.001
Friedman Valence (Rot/Blau/Weiss): χ²=2.713, p=0.258

Post-hoc Arousal (Wilcoxon + d):
rot vs blau: W=200.500, p_corr=0.428, d=0.246
rot vs weiss: W=126.500, p_corr=0.005, d=0.585
blau vs weiss: W=51.000, p_corr=0.006, d=0.566

Post-hoc Valence (Wilcoxon + d):
rot vs blau: W=212.000, p_corr=1.000, d=0.000
rot vs weiss: W=134.500, p_corr=0.070, d=-0.381
blau vs weiss: W=205.000, p_corr=0.122, d=-0.339
```

Arousal & Valence: Wilcoxon – Materials

```
Wilcoxon Arousal Material (Holz vs Beton): W=176.000, p=0.526, d=0.058
Wilcoxon Valence Material (Holz vs Beton): W=88.000, p=0.008, d=0.463
```

Spatial Environment – One Sided Wilcoxon

```
=== One-sample Wilcoxon vs. 3 — Arousal by Spatial Background ===

--- rot_aro ---
in einer Stadt  N=11  W=13.0  p(>3)=0.765  p(<3)=0.765
auf dem Land    N=16  W=29.0  p(>3)=0.117  p(<3)=0.883
in einer Agglomeration N=12  W=10.0  p(>3)=0.124  p(<3)=0.876

--- blau_aro ---
in einer Stadt  N=11  W=22.0  p(>3)=0.264  p(<3)=0.736
auf dem Land    N=16  W=49.0  p(>3)=0.596  p(<3)=0.596
in einer Agglomeration N=12  W=0.0  p(>3)=0.988  p(<3)=0.012

--- weiss_aro ---
in einer Stadt  N=11  W=9.0  p(>3)=0.902  p(<3)=0.098
auf dem Land    N=16  W=4.5  p(>3)=0.998  p(<3)=0.002
in einer Agglomeration N=12  W=3.5  p(>3)=0.994  p(<3)=0.006

--- Holz_aro ---
in einer Stadt  N=11  W=9.0  p(>3)=0.631  p(<3)=0.631
auf dem Land    N=16  W=11.0  p(>3)=0.991  p(<3)=0.009
in einer Agglomeration N=12  W=7.0  p(>3)=0.947  p(<3)=0.053

--- Beton_aro ---
in einer Stadt  N=11  W=0.0  p(>3)=0.988  p(<3)=0.012
auf dem Land    N=16  W=9.0  p(>3)=0.921  p(<3)=0.921
in einer Agglomeration N=12  W=3.5  p(>3)=0.971  p(<3)=0.029

=== One-sample Wilcoxon vs. 3 — Valence by Spatial Background ===

--- rot_val ---
in einer Stadt   N=11  W=16.0  p(>3)=0.614  p(<3)=0.614
auf dem Land     N=16  W=52.5  p(>3)=0.500  p(<3)=0.500
in einer Agglomeration  N=12  W=12.0  p(>3)=0.905  p(<3)=0.095

--- blau_val ---
in einer Stadt   N=11  W=5.5  p(>3)=0.860  p(<3)=0.860
auf dem Land     N=16  W=33.0  p(>3)=0.686  p(<3)=0.686
in einer Agglomeration  N=12  W=4.0  p(>3)=0.833  p(<3)=0.833

--- weiss_val ---
in einer Stadt   N=11  W=10.5  p(>3)=0.070  p(<3)=0.930
auf dem Land     N=16  W=16.5  p(>3)=0.016  p(<3)=0.984
in einer Agglomeration  N=12  W=13.5  p(>3)=0.124  p(<3)=0.876

--- Holz_val ---
in einer Stadt   N=11  W=9.0  p(>3)=0.079  p(<3)=0.921
auf dem Land     N=16  W=18.0  p(>3)=0.011  p(<3)=0.989
in einer Agglomeration  N=12  W=2.5  p(>3)=0.023  p(<3)=0.977

--- Beton_val ---
in einer Stadt   N=11  W=6.0  p(>3)=0.958  p(<3)=0.042
auf dem Land     N=16  W=27.0  p(>3)=0.709  p(<3)=0.709
in einer Agglomeration  N=12  W=9.0  p(>3)=0.631  p(<3)=0.631
```

Spatial Environment – Cohen's *d*

```
=== rot_aro ===
in einer Stadt vs auf dem Land: Cohen's d = -0.50
in einer Stadt vs in einer Agglomeration: Cohen's d = -0.57
auf dem Land vs in einer Agglomeration: Cohen's d = -0.03

=== blau_aro ===
in einer Stadt vs auf dem Land: Cohen's d = 0.24
in einer Stadt vs in einer Agglomeration: Cohen's d = 1.01
auf dem Land vs in einer Agglomeration: Cohen's d = 0.70

=== weiss_aro ===
in einer Stadt vs auf dem Land: Cohen's d = 0.42
in einer Stadt vs in einer Agglomeration: Cohen's d = 0.40
auf dem Land vs in einer Agglomeration: Cohen's d = 0.00

=== Holz_aro ===
in einer Stadt vs auf dem Land: Cohen's d = 0.79
in einer Stadt vs in einer Agglomeration: Cohen's d = 0.61
auf dem Land vs in einer Agglomeration: Cohen's d = -0.13

=== Beton_aro ===
in einer Stadt vs auf dem Land: Cohen's d = -0.66
in einer Stadt vs in einer Agglomeration: Cohen's d = -0.29
auf dem Land vs in einer Agglomeration: Cohen's d = 0.34

=== rot_val ===
in einer Stadt vs auf dem Land: Cohen's d = 0.06
in einer Stadt vs in einer Agglomeration: Cohen's d = 0.39
auf dem Land vs in einer Agglomeration: Cohen's d = 0.32

=== blau_val ===
in einer Stadt vs auf dem Land: Cohen's d = -0.13
in einer Stadt vs in einer Agglomeration: Cohen's d = -0.62
auf dem Land vs in einer Agglomeration: Cohen's d = -0.34

=== weiss_val ===
in einer Stadt vs auf dem Land: Cohen's d = -0.07
in einer Stadt vs in einer Agglomeration: Cohen's d = 0.19
auf dem Land vs in einer Agglomeration: Cohen's d = 0.29

=== Holz_val ===
in einer Stadt vs auf dem Land: Cohen's d = -0.35
in einer Stadt vs in einer Agglomeration: Cohen's d = -0.33
auf dem Land vs in einer Agglomeration: Cohen's d = 0.02

=== Beton_val ===
in einer Stadt vs auf dem Land: Cohen's d = -0.70
in einer Stadt vs in einer Agglomeration: Cohen's d = -0.71
auf dem Land vs in einer Agglomeration: Cohen's d = 0.09
```

AI–Statement

Artifical Intelligence (ChatGPT, OpenAI) was used in this thesis as a supportive tool for spelling, translation, text formulation and for programming assistance in Python (e.g. statistical analyses). The conceptual ideas, structure, interpretations and conclusions of the thesis are entirely the author's own.

Personal Declaration

I hereby declare that the submitted thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the thesis.

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Place, Date: Zürich, 29.08.2025

Signing: