Design Science

Virtual design context: a VR-driven approach to contextual architectural design; a preliminary taxonomy for developing immersive contexts

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Abstract

This paper aims to theorise how virtual reality (VR) can contribute to the development of contextual architecture. We start by considering how an architectural context may translate into a virtual domain, introducing preliminary definitions of what a virtual design context (VDC) could entail. We then discuss a proposed taxonomy that guides the creation of such a VDC, anchored in principles drawn from virtual realism in art philosophy and contextualism within architecture. This taxonomy is envisioned as a preliminary framework for developing VR-driven design environments with a focus on context. Next, we conducted expert user-testing with 24 architects using two VDCs developed according to the taxonomy. The goal of this step was to gain insights regarding the cognitive load of designers and their user experience while engaged in different types of VDCs. Results suggest that designing in these virtual environments enhanced contextual learning, supported conceptual and creative insight and helped maintain manageable cognitive load. The paper concludes by underscoring the real-world applicability of this taxonomy, highlighting how VR can breathe new life into contextual design, not by reducing context into a digital replica, but by opening new dimensions through which its richness can be explored, interpreted and reimagined.

Keywords: Virtual Reality, Contextual Architecture, Virtual Design Context, Immersive Virtual Environment, Cognitive Load

Received 19 March 2025
Revised 30 October 2025
Accepted 31 October 2025

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Des. Sci., vol. 11, e53
journals.cambridge.org/dsj
DOI: 10.1017/dsj.2025.10041

the Design Society a worldwide community
Cambridge University Press

1. Introduction

Driven by its capacity to inspire new possibilities and innovative solutions, researchers across multiple disciplines have shown growing enthusiasm for the transformative potential of virtual reality (VR). Conceptually, VR has been explored not only through a technical lens, encompassing computer science and behavioural interfaces (Fuchs, Moreau & Guitton 2011), but also from a philosophical perspective, examining how it compares to “actual reality” and what it truly means for an environment to be “virtual” (Heim 2000). The immersive nature and strong sense of presence afforded by VR have motivated scholars to investigate its applications in diverse fields (e.g., Tao *et al.* 2021; Lege & Bonner 2020). Much of this research centres on using VR to develop VE with broad-ranging purposes, such as training, gaming, visualisation and presentation of final products and even meditation (Sherman & Craig 2018). More recently, however, a significant new focus has emerged, positioning VR as a catalyst for creativity and a medium conducive to design.

As a medium offering numerous advantages to design professionals (Saorin *et al.* 2023), VR is gaining increasing traction as a complementary tool that enhances the design process (George & Summerlin 2018). While existing scholarship consistently underscores the benefits of VR technology, its core contributions to design research and practice include the capacity to navigate both interior and exterior spaces interactively and to examine design proposals throughout the various phases of development (Li, Yan & Gu 2018). In particular, VR has demonstrated its value in supporting participatory design processes (Davies 2004), showcasing final concepts to designers for added review and communicating finished ideas to clients (Berg & Vance 2017). A growing body of work also highlights how incorporating VR into different stages of the design cycle can bolster creativity and productivity (Paes, Arantes & Irizarry 2017; Paes, Irizarry & Pujoni 2021; Doma & Şener 2022). These advancements underscore VR's potential to reshape how design proposals are conceived and refined. Among the disciplines positioned to benefit most from these breakthroughs, architecture stands out, with advocates highlighting VR's ability to enhance collaboration (Yu *et al.* 2022, Yu, Gu & Masoumzadeh 2024), communication (Wen & Gheisari 2020) and creativity (Yang & Lee 2020) throughout the design process.

Within architectural design, contextual considerations (those centred on the physical, cultural and historical aspects of a site) play a pivotal role in shaping both process and outcome. The concept of "contextual architecture" originated in philosophical explorations of phenomenology and place in and after the 1980s (Norberg-Schulz 1982). It emerged as a direct critique of the universalising tendencies of modernism, advocating instead for designs that meaningfully respond to the environment, cultural background and history of a given site. This approach promotes a nuanced understanding of place, resulting in architectural works that align with and enrich their settings.

Despite the importance of contextual architecture, there remains a significant gap in discussions on how VR could support or transform contextual thinking. Given the heightened interest in deploying VR as a design platform, this omission grows more pressing. Notably, the majority of creative VR software places designers in isolated, abstract virtual spaces, underscoring the need to explore how contextual elements could be integrated into such environments. Designing in virtual environments without attention to real-world settings risks a return to the modernist traditions that contextual design originally sought to challenge; namely, a tendency to disregard site-specific conditions and nuances.

This relative absence of discourse may stem from a dearth of theoretical grounding and an accompanying lack of conceptual frameworks addressing whether, or how, context itself can be virtualised. Such a gap is particularly consequential for architecture, where the design process depends heavily on immersing practitioners in site-specific characteristics. To address this need, the

https://doi.org/10.1017/dsj.2025.10041 Published online by Cambridge University Press

present paper proposes a theoretical framework that synthesises insights from philosophy of the arts and architecture, examining the implications of virtualising context and how these virtual contexts might be crafted to support more robust contextual thinking in architectural design. To achieve this objective, the paper first revisits core dimensions of contextual architecture before examining how VR technology could enhance and expand these dimensions.

In addition to this theoretical inquiry, this study introduces a preliminary taxonomy and framework for creating VDCs in VR, specifically aimed at supporting contextual thinking in architecture and then empirically tests the designers' experience while designing in exemplary VDCs developed using the proposed taxonomy. Twenty-four expert architects participated in user-testing of VDCs developed according to this taxonomy, providing data on cognitive load, usability, and contextual learning outcomes. This empirical approach enables a preliminary assessment of how well taxonomy-based VDCs can foster contextual insight, creative ideation and conceptual clarity, while also highlighting the practical challenges and limitations of integrating VR into context-driven architectural design. By combining theoretical development with user-based evaluation, this research seeks to advance a more nuanced understanding of both the opportunities and constraints associated with virtualising architectural context.

2. Reframing context in architecture: a virtual shift

Architecture is interwoven with its surroundings, shaped by an array of social, physical, political, cultural and historical considerations (Masoumzadeh, Bosman & Osborne 2023). Contextualism arose to address these multi-faceted challenges, emphasising coherence and continuity when introducing new buildings into existing environments. Analysis of existing architecture, therefore, becomes pivotal in a designer's decision-making process for contextual design (Lambe & Dongre, 2016). Contextual architecture responds to the specific characteristics of a site, reflecting a set of values rather than any single architectural style. Cohen underscores the importance of acknowledging or incorporating local environmental features (Jon-Nwakalo & Odum 2018), while Nasr (2015) adds a systematic perspective by suggesting an evaluation of physical and non-physical attributes (man, site and materials) in both the near and distant contexts.

Even though context is recognised as crucial, Kang (2012) points out that it is frequently neglected or reduced to simplistic standards in many architectural practices. Factors like planning regulations often limit material choices or building proportions, while discussions of context sometimes prioritise scientific or quantitative measures at the expense of historical and cultural considerations. Moreover, treating context as a static entity overlooks how it evolves over time, a reality especially important in adaptive re-use or renovation projects. Ultimately, these tendencies can lead to an arbitrary understanding of context, thus challenging architects to create buildings that genuinely engage with and contribute to their surroundings.

Building upon these challenges, a notable solution lies in shifting towards VR as a medium for contextual architectural design. Recent studies underscore how VR can enrich the entire design process by creating more engaging, immersive, and realistic workspaces (Zheng 2022). In design education, for instance, VR has demonstrated its capacity to improve both teaching methods and student learning

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outcomes by offering interactive simulations that bring theoretical knowledge to life. Beyond education, researchers such as Paes *et al.* (2017) and Doma & Şener (2022) highlight how VR's integration throughout various stages of the design cycle may stimulate innovation, creativity and productivity; key attributes in effectively responding to complex, multi-layered contexts.

This potential is largely attributed to the experiential qualities VR provides. Unlike conventional tools, VR invites designers, stakeholders and end users into immersive environments where they can virtually explore design concepts while immersed in the site rather than relying on abstract representations. As a result, the technology can help bridge the gap between conceptual thinking and actual site conditions, potentially addressing the critique that much of the contextual design process still happens behind office desks. VR offers a novel way to engage with site-specific parameters through immersive interaction, which can complement existing methods of real-world observation and analysis. Moreover, VR's focus on spatial presence (Tavinor 2019) offers unique advantages when it comes to contextual design. Spatial presence denotes the sensation of physically "being" in a virtual space; once designers genuinely feel located within the site's digital twin, their decision-making can become more contextually attuned. The distinction between technological refinements (like frame rates or hardware improvements) and purposeful creation of immersive virtual environments thus becomes crucial: while technical progress enhances user comfort, the design of VR scenarios themselves—through lighting, material expression, geometry and environmental cues—arguably does more to influence design thinking. Consequently, the virtual shift pivots from mere technological novelty to a more profound reorientation of how architects perceive and manipulate their contextual environments.

2.1. Designing in-site rather than on-site

A core benefit of VR in architectural practice lies in its capacity to enable designing "in-site," where immersive contexts foster a tighter link between the conceptual phase and the real-world setting. Traditional approaches, such as on-site sketching, remain valuable for developing preliminary ideas and capturing immediate impressions (Jenkins 2022). However, incorporating VR into these methods has the potential to preserve the tangible benefits of physically being on-site while also addressing the limitations of sketching alone. For example, designers can switch between a physical location visit and an immersive VR session, ensuring that spatial analyses, changes in lighting conditions and user circulation patterns are all revisited in real time.

Adopting additional technological tools likewise opens new avenues for enhancing both visualisation and participatory design. Skov *et al.* (2013) proposed the use of ArchiLens, a mobile system employing augmented reality (AR), for on-site 3D visualisation of houses, thereby encouraging creative participatory design. Their findings emphasise the benefits of integrating emerging technologies to help designers and end users envision future developments within their respective contexts. Though other studies similarly highlight AR's potential (e.g., Nofal *et al.* 2018; AlFadalat & Al-Azhari 2022), the question of how VR might further bolster contextual thinking remains underexplored in the literature. This oversight may be attributed to challenges involved in virtualising the design context, coupled with a lack of theoretical frameworks that identify what aspects of the site could be

https://doi.org/10.1017/dsj.2025.10041 Published online by Cambridge University Press

included in a virtual representation and how such representations might influence both design outcomes and user engagement.

Likewise, VR can strengthen the participatory dimension of contextual design. Whereas earlier solutions, such as interactive CAD models, sometimes fell short of granting stakeholders an intuitive feel for a project's relationship to its surroundings, VR can reduce some of the abstraction found in traditional visualisations and may help foster discourse between architects, clients and community members; particularly when used alongside physical models or in-situ visits.

Furthermore, the technology addresses many constraints identified by previous research into contextualism and its practical implementation. Difficulties in simulating historical or cultural nuances, for instance, can be mitigated through immersive virtual environments that include 3D scans of heritage buildings, local textures, and relevant environmental data. By blending real-world references with contemporary design interventions, VR applications move beyond simplistic or purely symbolic acknowledgments of context, enabling nuanced analyses of site identity. In doing so, architects may be able to overcome the static or purely formal treatment of context criticised by Kang (2012) and instead establish iterative, dynamic dialogues with place. By examining how VR not only changes the means of design but also reshapes the ways architects conceive and respond to their sites, it becomes evident that this virtual shift has the potential to tackle longstanding shortcomings in contextual architectural design. Existing research shows that VR can heighten collaboration (Yu *et al.* 2022), enhance communication (Yang & Lee 2020) and ultimately broaden creative thinking through interactive spatial exploration. Yet, as the technology gains wider adoption, deeper theoretical work is needed to define the implications of an environment being virtual – hereafter referred to as "virtual design context" (VDC) – differentiating it from conventional 3D modelling or superficial representations of site attributes.

Despite these advantages, it is important to recognise that VR should be regarded as a powerful support tool for contextual design, not a wholesale replacement for direct, in-situ engagement with the site. Physical site visits provide irreplaceable sensory, cultural and emotional data that enrich the design process in ways that cannot be fully replicated in virtual settings (Sherman & Craig 2018; Jenkins 2022). VR is most effective when integrated strategically alongside traditional methods, allowing designers to alternate between real and virtual experiences, each informing the other. This combined approach not only preserves the benefits of embodied, place-based engagement but also leverages the flexibility and immersive visualisation that VR uniquely offers. In this way, VR becomes a means to augment, rather than substitute for, the nuanced contextual understanding that is fundamental to responsive architectural design.

Accordingly, the next step in this inquiry involves analysing the philosophical underpinnings of VR and virtuality to assess how a real-world context might be meaningfully virtualised. In order to do so, this paper will reference Tavinor's (2021) examination of VR aesthetics to discuss why a VR experience may feel more immersive or "real" than other types of representation, and then attempt to translate these insights into architectural workflows and argue how they can lead to new frameworks, tools and best practices specifically focused on maintaining contextual fidelity in a virtual domain. Doing so will contribute towards advancing VR from a novel tool into a design medium and how it calls for closer scrutiny of

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the ways in which designers craft immersive virtual environments; and what it means for both old and new structures to coalesce in a shared digital space.

Building on this rationale, this paper addresses the following research questions:

RQ1 : To what extent is it meaningful and theoretically defensible to virtualise architectural design context within immersive virtual environments?

RQ2 : How can a coherent taxonomy be formulated using the existing literature to guide the development of VDCs for architectural design?

RQ3 : How do expert architects perceive and evaluate the contextual learning outcomes and creative stimulation associated with engaging with taxonomy-based VDCs?

RQ4 : How do expert architects perceive and evaluate the cognitive load impacts when engaging with different types of VDCs developed according to this taxonomy?

The following sections outline the theoretical basis for the VDC and report on empirical testing with expert architects.

3. Exploring virtuality and the VR medium: can a virtual context exist?

The term "virtual" frequently appears alongside concepts such as virtual meeting, virtual environment or virtual reality. Yet, how does this "virtual" descriptor alter the meaning of the base term it modifies? For instance, in what ways does a virtual meeting differ from a conventional one? Tavinor (2021) addresses this question by contrasting the virtual not with the real, but with the actual, proposing that a virtual *x* is almost – though not exactly – an *x*. Rather than negating the core purpose or function of the original, the virtual rendition preserves its essential efficiency while presenting it in an unfamiliar or non-customary form. A useful example is the idea of a virtual museum in a VR environment, where a virtual sculpture embodies the essential qualities of a real-world sculpture, yet exists in an immersive digital space. Users can interact with and perceive this sculpture in ways that mirror engagement with its real-world counterpart, albeit with distinct, digitised nuances.

Although this conceptualisation of virtuality is not novel, Tavinor's perspective on "virtual remediation" is especially noteworthy. He defines virtual remediation as an intermediary condition situated between *representation* and *reproduction*, emphasising that it should remain unfamiliar enough to feel distinctly "virtual" yet still preserve the efficacy of its real-world referent (Tavinor 2021). In applying the notion of virtual remediation to VR, Tavinor highlights how VR remediates our experiential and perceptual interactions with the world. Historically, pictures and paintings have served as means of representing spatial experiences; VR enriches this lineage by introducing dynamic, three-dimensional imagery seen from a virtual camera's viewpoint, tracked by head movements and rendered stereoscopically through a headset. Such versatility underscores the boundless potential of VR to facilitate virtualisation. One way to illustrate this is through the virtual remediation of a traditional architectural element – say, a column. Within a virtual architectural environment, a digitally rendered column may adopt a sleek, modern style or an ornate, classical design, without losing its essential load-bearing "column-ness." While any material or aesthetic may be applied, the column's core

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identity as a supportive structural form must remain intact to be recognised as a "virtual column." In other words, VR provides a broad creative canvas for altering the experiential qualities of architectural features, yet the design must not compromise their defining functions or roles.

In exploring virtual remediation further, Tavinor (2019) distinguishes two complementary concepts: virtual fictionalism and virtual documentary. Virtual fictionalism focuses on generating entirely new experiences or worlds – prevalent in gaming – by altering visual, perceptual or spatial elements in the VE. By contrast, virtual documentary seeks to remediate existing actualities, offering novel ways of *seeing* and *experiencing* what already exists rather than replicating it precisely. These two pathways underscore the range of VR's objectives: from igniting imagination through fictional settings to re-presenting reality in ways that enrich understanding of the actual world.

Applying these insights to architecture prompts the question of whether/how the context of a design can undergo a form of "virtual remediation." Understanding the implications of virtualising context requires both a theoretical and practical framework. The premise here is that VR has the potential to generate an immersive, interactive "virtual context," which, unlike conventional documentation methods, could further capture the dynamism and complexity of an architectural setting. This viewpoint, defined in the next section, opens the door to new ways of seeing design sites and fosters deeper, more intuitive engagement with them.

3.1. Virtual design context

At a glance, a VDC may resemble a virtual environment (VE), but making a clear distinction between the two is critical. Virtual environments, as Ellis (1994) explains, refer broadly to any simulated domain in which users can carry out activities – from training simulations to virtual tours. VDC, however, serves a narrower, design-specific role: it reinterprets a real or imagined context (via virtual documentary or virtual fictionalism) for the explicit purpose of informing design decisions. As Çizgen (2012) notes, context in architecture is fundamental to data collection, influencing how designers approach their work. By incorporating contextual information into a VE specifically tailored for architectural problem-solving, a VDC preserves and conveys critical site data. Urban designers, for example, might produce a VDC representing a proposed masterplan, allowing architects to place future structures inside that virtual landscape for a high-fidelity preview of how a development interacts with surrounding environments.

This approach diverges from traditional 2D or 3D documentation in significant ways. Typically, 3D models are projected onto a 2D screen – what Tavinor (2021, 65) calls a form of picturing – creating an approximate sense of spatiality. Within VR, however, modelling extends beyond a standard monitor; binocular lenses eliminate visual distance, immersing the user in the environment. As Grabarczyk & Pokropski (2016, 35) emphasise, presence in VR relies on the user's belief that they are located in an "alternative place," rather than merely viewing a screen or a photo realistic picture. Slater (2009) refers to this phenomenon as *spatial presence*, the illusion of actually inhabiting a virtual locale. In VR, "seeing" the screen itself undermines the intended experience. This capacity for genuine presence constitutes the key distinction between conventional picturing methods and VR-based documentation of architectural context.

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Closely related is the idea of "egocentric picturing" (Whittaker 2023), which further reveals how VR can transform our perception and interaction with architectural contexts. Within a VE, users may experience patiency – a sense of "vulnerability" (Dooley 2017, 10), and *being acted upon* or *receiving* actions and stimuli, as opposed to *agency*, which is the experience of initiating or controlling actions – that encourages them to emotionally invest in the virtual space. While patiency is often linked to scenarios like horror video games, it can similarly evoke rich emotional responses during design exploration. For instance, Sadeghi Habibabad *et al.* (2022) show that in a religious setting, users immersed in VR may experience a sense of spirituality. Extrapolating from this, designing within such a VR environment could allow architects to better intuit how users might relate to a sacred place, enhancing empathy and understanding of its cultural or emotional dimensions.

While much of the current development in immersive virtual environments focuses on visual and auditory immersion, it is essential to recognise that architectural experience is fundamentally multisensory. Senses such as smell and touch contribute significantly to our perception of place, atmosphere and material qualities, and their absence in most virtual environments may limit the authenticity and depth of contextual immersion (Drobnick 2006; Pallasmaa 2012). Recent advances in technology are beginning to address these gaps through the integration of olfactory and haptic interfaces, which offer new opportunities for creating richer, more nuanced virtual contexts (Ranasinghe *et al.* 2018; Martinez, Pereda & Lopez 2021). Additionally, the combination of VDCs with mixed reality (MR) platforms holds considerable promise. MR can blend digital and physical realities, enabling designers to overlay virtual contextual information onto real-world sites or augment in-situ experiences with digital cues, multisensory feedback and interactive content. This hybrid approach could facilitate more holistic and embodied engagement with architectural context, bridging the limitations of purely virtual or purely physical design methods.

In architectural practice, a VDC can act as a novel form of documentation (Figure 1) that merges the benefits of remote references – such as maps, photographs or written data – with the immediacy of on-site methods like sketching or field observation. Rather than merely supplementing existing documents, a VDC provides a new medium for capturing and conveying spatial nuances, leveraging "spatial presence" and "patiency" to enable seamless transitions between immersive exploration and abstract planning. Much like the role of AI in creative processes, integrating VR into architectural workflows can heighten interactivity and immersion, thereby sparking more inventive design solutions. Although additional empirical work is needed to confirm these impacts, current studies already point to increased creativity across various design domains through the use of VR (Berni & Borgianni 2020; Guan *et al.* 2023).

Figure 1. VDC as a new way of documenting architectural context.

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While this paper emphasises the perceptual and informational dimensions of context in virtual environments, it is important to acknowledge that the notion of "context" in architecture is much broader and inherently multifaceted. Context not only encompasses the physical and sensory characteristics of a site but also its social, political, economic and cultural dimensions (Dovey 2010; Jones 2022). The experience of presence in VR, although immersive, cannot fully substitute for the embodied, multisensory and negotiated qualities of in-situ engagement (Warren 2021). Future research and the ongoing development of VDCs must remain attentive to these broader dynamics, recognising the risks of technological solutionism and the challenge of ensuring that virtual representations do not flatten or oversimplify the complexities of real-world contexts. By situating VDCs within this wider theoretical discourse, this work aims to contribute to a more robust, critical and situated understanding of contextualism in digital design.

In what follows, attention will turn to the process of formulating and refining a VDC. Recognising that creating VR experiences involves not just technical prowess but also an artistic dimension (Heim 2000), the following sections will delve into the concept of *virtual realism* – a term introduced by art philosophers to explore VR – to frame how contexts can be methodically remediated. By applying these philosophical underpinnings, we can establish a replicable roadmap for fashioning VDCs that meaningfully capture a site's essence while taking advantage of VR's capacity for immersion and innovation.

4. Aesthetics of VDC: virtual realism – photo realism and stylised realism

Realism has been a longstanding pursuit both in traditional artistic attempts, such as paintings, and in developing virtual environments; it is often considered the "holy grail" in the literature of VR (Chalmers & Ferko 2008). In the context of VR, realism refers to the ability of virtual environments to provide visual stimuli that closely resemble real-world scenes. However, virtual realism extends beyond mere replication of physical reality into a VE. Unlike realism in traditional computer graphics, virtual realism encompasses not only visual fidelity but also the physiological and psychological responses of users within virtual environments. Presence, as defined earlier, plays a crucial role in evaluating realism in virtual environments (Hvass *et al.* 2017).

Studies suggest that virtual realism is associated with an enhanced sense of presence, which evokes stronger emotional responses from users (Ibid). Thus, virtual realism involves not only visual fidelity but also considerations of user experience and emotional engagement. In other words, achieving virtual realism in a VE does not rely solely on high fidelity – such as high-quality textures and real-time lighting. Even without these elements, a VE can still feel authentic if it successfully instils a sense of presence and elicits psychological and physiological responses from users. This perspective bears potential because it enables the creation of environments with lower levels of complexity while still conveying a sense of reality and presence to the user.

Seeking to clarify the different senses of realism experienced by users within virtual environments, Tavinor (2019, 2021) identifies five distinct aspects of virtual realism: *immersion, psychological realism, depictive realism, ontological realism and functional realism.* While our study will primarily focus on psychological realism

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and depictive realism, it is important to briefly consider the remaining categories to situate these discussions:

4.1. Immersion

Immersion, as defined by Witmer & Singer (1998), refers to a psychological state where individuals perceive themselves to be enveloped by, included in and interacting with an environment that provides a continuous stream of stimuli and experiences. Therrien (2014) describes sensory immersion as feeling transported to a non-immediate reality within mediated representations. However, immersion's relation to the vividness or credibility of represented realities does not always correlate with the psychological impression of realism; it is possible to experience immersion even in highly unrealistic VR settings (Lawson 2014). Moreover, the realism in VR can paradoxically induce motion sickness (Saredakis *et al.* 2020), complicating immersion's role as a straightforward measure of realism.

4.2. Functional realism

Functional realism pertains to the sense of virtual realism reliant on a virtual medium's ability to preserve the function of its real-world counterpart (Tavinor 2018). This concept is exemplified when a virtual medium enables users to see and catch a virtual ball, mirroring the function of interacting with a real ball (Pan & Niemeyer 2017, cited in Tavinor 2019). Functional realism also extends to virtual items like classrooms, where the preservation of crucial functions allows them to be perceived and treated as actual instances of their real-world counterparts. Thus, functional realism underscores a structural or functional correspondence between virtual and actual items – a fundamental aspect of virtuality.

4.3. Ontological realism

Ontological realism suggests that VR objects are not merely fictional but are actual digital entities created by computational processes (Tavinor 2019). These digital objects form the real basis of our experiences in VR, making virtual reality a genuine field where virtual objects have real existence. This contrasts with earlier views focusing primarily on the appearance of virtual objects rather than their underlying nature.

Together, immersion, functional realism and ontological realism depend largely on the technological capabilities of VR systems and the nature of virtual objects. Their experiential qualities cannot be altered merely by software interventions. The presence of these three aspects is essential for users to engage meaningfully with virtual environments and perceive them as credible extensions of reality. However, since software interventions do not alter the quality of these aspects, our study will concentrate on the other adjustable aspects of virtual realism, as outlined below.

4.4. Psychological realism (subjective realism)

Unlike immersion, functional realism and ontological realism, *psychological realism* can be shaped or adjusted via design and narrative strategies. Psychological realism refers to the immersive quality that makes virtual worlds feel convincingly

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real to users, often eliciting genuine responses and behaviours (Tavinor 2019, 2021). Spatial presence – a key component – occurs when users feel physically situated within the VE, a sensation rooted in perceptual illusions and cognitive processes (Murphy 2017: 4).

Artistic changes in scenery, lighting or characters can evoke diverse feelings and experiences, highlighting the relationship between design choices and users' perceptual and emotional engagement in VR. In a similar vein, Gonçalves *et al.* (2022) distinguish between *subjective realism* (akin to psychological realism) and *objective realism* (akin to depictive realism). Subjective realism focuses on personal perceptions of authenticity within a VE, independent of how faithfully it mirrors real-world laws. Users can experience a strong sense of psychological realism if the VE's internal rules are coherent – even if they deviate from the physics of the real world.

4.5. Depictive realism (objective realism)

Where psychological realism is mainly about how "real" a VE feels subjectively, *depictive realism* concerns the accuracy of virtual representations with respect to real-world visual and spatial attributes (Tavinor 2019, 2021). Historically, the concept of resemblance has guided realism in the arts, from the invention of linear perspective in painting to the detailed modelling and rendering in modern VR (Slater *et al.* in Gonçalves *et al.* 2022). Depictive realism entails careful attention to geometry, lighting, and texture so that virtual scenes evoke a strong sense of authenticity and presence. Even slight discrepancies in scale or illumination can influence a user's sense of spatial orientation, presence and task performance.

Critically, achieving depictive realism is not only about technological precision (e.g., high-resolution rendering); it also involves informed artistic and design choices to recreate spatial relationships and perceptual cues. Nonetheless, *perfect* visual fidelity is not always necessary for a compelling experience. Psychological realism can arise through coherence and narrative acceptance, as users may fill in gaps where depictive fidelity is limited or intentionally stylised.

4.6. Photo realism and stylised realism

Within the broader scope of depictive (objective) realism and psychological (subjective) realism, this paper will employ two particular aesthetic terminologies (*photo realism* and *stylised realism*) to demonstrate how different forms of realism can be leveraged in VDCs.

4.6.1. Photo realism

Photo realism is a form of depictive realism that aims to replicate real-world appearances and lighting conditions with as much fidelity as possible. It relies on high-resolution textures, advanced rendering algorithms and carefully calibrated lighting models to achieve realism that can approach photographic quality (Slater 2009; McMahan *et al.* 2012). Aspects such as geometric accuracy and physically based rendering techniques often underpin this approach, ensuring that materials and lighting behave in ways consistent with their real-world counterparts (Debevec 1998).

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Photo realism aligns closely with depictive (objective) realism, as it attempts to faithfully reproduce what users would see in real life. This approach can be particularly useful in applications requiring exact visual fidelity, such as architectural walkthroughs or medical simulations, where precise rendering of spatial and material properties is critical to the user's experience and performance.

4.6.2. Stylised realism

By contrast, stylised realism still operates within the framework of depictive realism but deliberately incorporates artistic or aesthetic modifications. This might involve simplified textures, exaggerated forms or distinct colour palettes. For instance, stylised virtual environments can use painterly effects, or minimalistic geometry to convey only the essential features of the environment (De Carvalho & Tavares 2019; Johnson, Bruno & Scolaro 2020).

Although stylised realism does not reproduce every visual detail of real-world scenes, it retains enough coherence and consistency to anchor users within the VR experience. This approach can simultaneously maintain users' sense of presence (psychological realism) by relying on well-established rules and internal logic, even if the visual style is not photorealistic. Additionally, stylised realism can be less computationally demanding than photo realism, allowing for smoother frame rates and broader accessibility without sacrificing a sense of authenticity or emotional impact (Reichlinger & Grosch 2017).

5. Remediating design context into VDC

In this study, architectural context is not treated merely as a conceptual or environmental backdrop but as a set of identifiable and translatable information layers that can inform the design of VDCs. These layers include spatial and formal characteristics (such as density, massing, geometry and spatial hierarchy), environmental conditions (including lighting, vegetation and ambient atmosphere), material and visual language (such as surface finishes, colour schemes and symbolic markers) and cultural or social cues (such as public-private thresholds, culturally specific iconography or patterns of use).

These contextual layers are not static or universally transferable but must be selectively interpreted and curated depending on the design intent and the specific affordances of the virtual medium. Rather than aiming to replicate the real world in totality, VDCs can emphasise particular spatial, cultural or environmental cues based on the desired level of fidelity, user interaction and conceptual focus. This involves choices around which aspects of context are foregrounded or abstracted, such as using symbolic massing in place of detailed forms, ambient lighting to shape atmosphere, or interactive elements to evoke social cues. In this way, architectural context becomes an operational framework for selectively embedding information; designed not as a comprehensive mirror of reality but as a structured medium for cognitive engagement, creative exploration and spatial reasoning in virtual design environments.

5.1. Which type of virtual realism?

According to Gonçalves *et al.* (2022), objective realism can significantly influence user performance in virtual environments. High-fidelity simulations such as

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flight-training modules or surgical environments exemplify scenarios where **photo realism** is crucial for skill transfer and realism. Yet, extensive detail or overly busy visuals do not always help. Excessive complexity can induce cognitive overload or cybersickness, ultimately hindering performance (Stanney, Mourant & Kennedy 1998; Kline & Witmer 1996). Thus, while objective realism can heighten authenticity, it requires careful moderation to ensure that its benefits – improved user engagement or accurate skill acquisition – are not undermined by system demands or sensory fatigue.

To navigate this balance, it is helpful to conceptualise the remediation of objects and spaces from the real world into a VDC through a framework that integrates both depictive and psychological considerations. Such a framework involves the multi-step process showcased in Figure 2 and described below.

5.1.1. Step (1) Identifying essential features

Designers must determine which geometric, illuminative and textural attributes are most relevant to the VE's goals. In some contexts, like architectural review, precise building proportions and site topographies are pivotal. However, not all scenarios demand full photo-realistic accuracy. For example, a stylised approach could suffice or even excel if the objective is to highlight key design elements or convey a unique aesthetic. By isolating "essential features," designers conserve resources and reduce unhelpful complexity.

While this step focuses on identifying key spatial and cultural features to include in a VDC, we acknowledge that context is often revealed through unplanned, emergent moments. For this reason, VDCs should not be overly prescriptive. Instead, they should allow space for interpretive openness, flexibility and user-driven exploration; embracing serendipity as a valuable part of contextual understanding rather than something to be eliminated. This may be considered through design strategies such as modular scene composition (where different contextual elements can be toggled on/off or rearranged) and layered information cues (such as audio, text or visual prompts revealed through interaction). However,

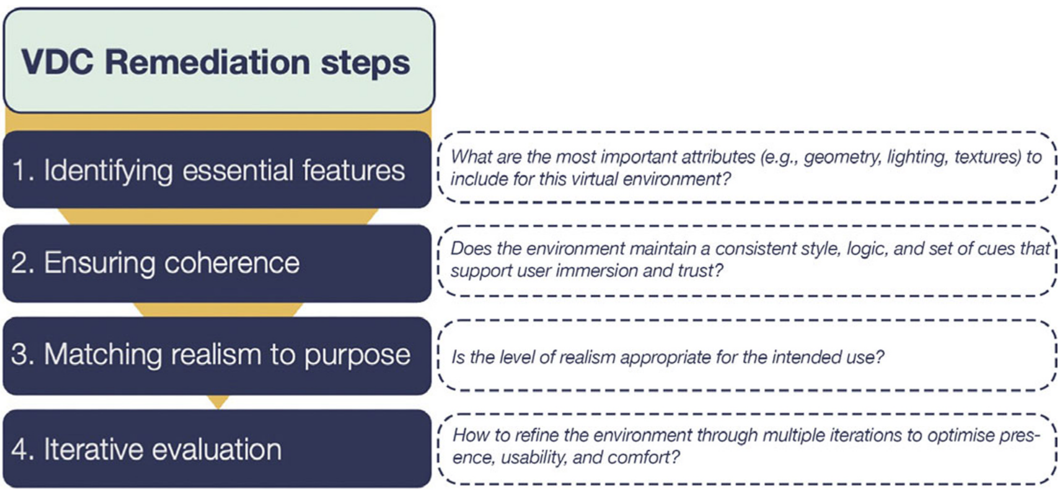

Figure 2. Steps for remediating design contexts into a VDC.

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even with such strategies, VDCs will inevitably miss certain sensory, social or atmospheric nuances that arise only through direct, real-world engagement. Therefore, we advocate for using VDCs not as substitutes for real-world context but as complementary tools that extend and deepen site understanding in conjunction with in-situ experience.

5.1.2. Step (2) Ensuring coherence

Beyond mere visual detail, psychological realism hinges on the VE's internal consistency; its "rules" and narrative logic (Skarbez, Brooks & Whitton 2017; Gonçalves *et al.* 2022). This might mean preserving culturally relevant cues, maintaining gravity-like behaviours, or upholding a unified artistic style. Whether the VE embraces photo realism or **stylised realism**, ensuring coherence fosters user trust and presence. Even if the environment diverges from true-to-life physics, a consistent "look and feel" encourages users to feel genuinely immersed.

5.1.3. Step (3) Matching realism to purpose

The ideal level of depictive realism varies depending on the design objectives. In high-stakes simulations (e.g., construction safety training), **photo realism** may be indispensable, helping users grasp site hazards with visual and material authenticity (Cox, Bown & Gkatzidou 2017). Conversely, early-phase architectural explorations or conceptual design sessions might benefit from **stylised realism**, which strips away certain details to emphasise form, layout or user flow. This approach can spark creativity and reduce the cognitive load of extraneous textures or hyper-realistic lighting.

In a more advanced VDC development, this binary can be transformed into a spectrum or a set of options that allow users to switch between different modes of realism depending on their purpose and design stage. Rather than committing to either stylised or photo-realistic environments from the outset, designers and stakeholders could toggle between modes, enabling a more responsive and task-specific engagement with the VDC.

5.1.4. Step (4) Iterative evaluation

Iterative feedback loops are integral to refining both depictive and psychological realism (Norman & Draper 1986; Nielsen 1993). Evaluations of presence, usability and user comfort guide incremental adjustments to geometry, lighting and textures (Sutcliffe & Gault 2004; Jerald 2015). With each iteration, designers can dial up or down specific real-world elements, tailoring the VE's realism (whether photo-realistic or stylised) to align with user preferences and task requirements.

When applying these principles to contextual architecture, one can imagine a continuum of realism ranging from highly photo-realistic representations that meticulously capture lighting and material properties (objective realism) to visually or conceptually **stylised** settings designed to evoke emotional responses or highlight specific design concepts (psychological realism). This approach to virtual remediation is not simple imitation. Following Tavinor (2021), virtualisation involves reframing how physical or conceptual elements function in digital space. Some elements may be pared down or removed, yielding improved conceptual clarity or a more pointed focus on key contextual features. For example, an

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architect might employ **stylised realism** to accentuate volumes and spatial relationships in an early sketch model, whereas subtle environmental audio cues or weather effects could bolster the subjective realism when seeking to immerse stakeholders in a project's cultural atmosphere.

User preference and perceived realism also factor into these decisions. Gonçalves *et al.* (2022) observe that users often favour higher objective realism for comfort and believability. However, over-committing to photo realism may cause increased resource usage, heightened computational demands, or more complex navigation. Conversely, stylised representations can sometimes reduce visual clutter, optimise performance and still maintain sufficient plausibility to engage users in meaningful ways – especially if the environment's internal logic remains consistent. The same logic extends to audio realism, which can be invaluable for directing user attention or evoking stress conditions that prompt design modifications. Haptic feedback, if available, could further deepen users' material understanding of surfaces, merging multiple forms of realism (visual, auditory, tactile) into an enriched design experience.

By carefully weighing photo realism against stylised realism, designers can select an optimal balance of fidelity and abstraction for each project stage. This flexibility enables VDCs to serve as effective, intuitive platforms for exploring context in architecture – guiding decisions, supporting stakeholder engagement and refining creative solutions in a precisely rendered or purposefully reduced digital realm.

In tandem with choosing the degree of realism, we may also face decisions about the type of VDC to employ; documentary or fictional. A documentary approach emulates an existing site as faithfully as possible, supporting robust site-specific analysis and stakeholder engagement. This is often useful for historical preservation, construction planning, and contextual fitting. A fictional approach, on the other hand, allows designers to explore hypothetical scenarios, radical morphological ideas or future cultural shifts unbounded by present-day constraints. Blending these approaches offers both rigo (grounded in real-world data) and imagination, leading to more expansive design explorations. For example, an architect might create a near-exact replica of a historic quarter for stakeholder review, then switch to a stylised overlay that experiments with potential urban modifications. Such flexibility underscores the broader utility of VDCs as tools for both preserving authenticity and stimulating creative transformation.

6. Towards a systematic approach for VDC remediation

In this section, the paper will attempt to put forward a preliminary taxonomy for creating VDCs in architectural design, **developed through a review of limited existing academic research** (Table 1). The taxonomy table presented in this study represents a new endeavour in theorising and systematising VDCs for architecture. It is important to acknowledge that there is not yet a substantial body of literature directly addressing the virtualisation of architectural context, nor are there well-established frameworks for guiding the development of immersive, context-driven virtual environments. Given the novelty of this approach and the limited theoretical and empirical foundation available, the taxonomy is best understood as a provisional framework. Its value and robustness must be established through ongoing empirical testing and iterative refinement. The present study's expert user

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Table 1. Taxonomy for remediating VDCs in contextual architecture

Remediation aspects	Considerations	Example scenarios
1. Design context	***1.1 Project stage***	**Early conceptual exploration:** Use stylised realism for rapid prototyping.
		Mid-phase design review: Blend stylised and photo-realistic elements.
		Final presentation & stakeholder engagement: Emphasise photo realism for immersion/trust.
	1.2 Design objectives & use-cases	**Spatial understanding**: Focus on basic geometry, minimal texturing.
		Cultural authenticity: Integrate localised textures, scents, ambient sounds.
		Emotional engagement & presence: Use photo-realistic lighting, realistic avatars.
		Task-driven scenarios: Tailor interactivity for navigation/decision-making.
2. Type of realism	***2.1 Stylised realism***	Minimal textures, simplified geometry, uniform lighting.
		Basic interactions (point-and-click/teleportation).
		Supports rapid iteration, lower computational load.
	2.2 Photo realism	High-resolution textures, dynamic lighting, realistic physics.
		Spatial audio, advanced haptics, potential scent cues.
		Ideal for final presentations and in-depth evaluations.
3. Factors	***3.1 Visual environment (textures, geometry)***	Range from basic, abstract forms to photo-realistic modelling with complex textures.
	3.2 Lighting & shadows	Static, uniform lighting versus dynamic, context-specific illumination.
	3.3 Physics & object behaviour	Simple, static objects versus physics-based interactions for functional realism.
	3.4 Avatars & agents	Abstract silhouettes versus fully animated, behaviour-rich avatars for social presence.
	3.5 Audio & soundscape	Minimal ambient hum versus spatially accurate, context-specific sounds.
	3.6 Haptics (touch feedback)	None versus nuanced tactile feedback to convey material realism.
	3.7 Olfactive (scent cues)	Typically absent versus targeted scent integration for cultural authenticity.
	3.8 Interaction mechanisms (gestures, locomotion)	Simple navigation versus full-body tracking and gesture-based control.
	3.9 Camera settings (field of view, depth of field)	Fixed viewpoint for stability versus adjustable parameters for comfort and realism.

Continued

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Table 1. Continued

Remediation aspects	Considerations	Example scenarios
4. Implementation strategies	***4.1 Stylised realism implementations***	Focus on essential forms, quick iteration, minimal resource demands.
	4.2 Photo realism implementations	Leverage advanced hardware, photorealistic rendering, and complex user inputs.
5. Contextual data integration	***5.1 Cultural & historical references***	Incorporate local markers, heritage elements and site-specific customs for authenticity.
	5.2 Environmental & climatic information	Mirror local daylight patterns, weather effects and ambient sounds.
	5.3 Material & construction data	Use regionally accurate materials, structural systems and construction details.
6. User experience & evaluation metrics	***6.1 Presence & embodiment assessments***	Examine how realism levels affect the user's "being there" sensation.
	6.2 Perceived realism & emotional resonance	Gather feedback (qualitative/quantitative) on immersion, comfort, believability.
	6.3 Task performance & decision support	Evaluate how effectively the VDC aids design navigation, planning or user comprehension.
7. Iteration & refinement process	***7.1 Feedback loops***	Use surveys, user testing, stakeholder input to refine design parameters.
	7.2 Adjusting realism	Scale stylised or photo-realistic elements as the project evolves and resources allow.
	7.3 Balancing authenticity & practicality	Continuously weigh the trade-offs between realism and abstraction to maintain efficiency.
8. Deployment & application	***8.1 Internal design team usage***	VDC as a collaborative design tool for iterative review, material selection, team alignment.
	8.2 Stakeholder & client presentations	Photo-realistic rendering to communicate design intent, credibility, and contextual fit.
	8.3 Educational & research use	Explore how varying realism influences architectural understanding, cultural interpretation, user engagement.
9. Long-term development & standards	***9.1 Best-practices guidelines***	Establish standard protocols for VR use in architecture, informed by project outcomes.
	9.2 Technological advancements	Integrate new VR hardware/software features, such as eye-tracking, improved haptics, higher resolutions.
	9.3 Cross-disciplinary input	Collaborate with cultural experts, psychologists, HCI specialists for greater contextual authenticity.

evaluation is offered as an initial contribution towards this aim, highlighting the necessity for further research to validate and enhance the taxonomy across a range of architectural design scenarios.

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6.1. Taxonomy development methodology

6.1.1. Search strategy

To develop the taxonomy presented in Table 1, a systematic search strategy was employed to identify and synthesise relevant academic sources spanning architecture, virtual reality, art philosophy, human–computer interaction and contextual design. Scopus, and Google Scholar were searched using a combination of terms including "virtual realism," "contextual architecture," "VR in design," "immersive environments," "realism," "fidelity," "design thinking" and "user experience." The initial pool of sources was further refined through citation chaining and cross-referencing influential works found in review articles and seminal books. Both recent empirical studies (e.g., Paes *et al.* 2021; Doma & Şener 2022; Yu *et al.* 2022; Gonçalves *et al.* 2022) and foundational theoretical texts (e.g., Tavinor 2019, 2021; Heim 2000; Norberg-Schulz 1982) were included to ensure that the taxonomy is grounded in both current practice and well-established conceptual frameworks. Priority was given to sources that directly addressed the translation of physical, cultural, and historical context into immersive digital environments or offered practical guidance for balancing realism and abstraction in design settings (e.g., Gonçalves *et al.* 2022).

6.1.2. Taxonomy categorisation

The readings identified through this search were then systematically mapped to the categories in the taxonomy based on the main concepts, methodologies, or case studies they discussed. For example, literature addressing levels of realism and the distinction between different kinds of realism (e.g., Tavinor 2021; Chalmers & Ferko 2008; McMahan *et al.* 2012) was assigned to the "Type of Realism" and "Implementation Strategies" categories. Studies on cognitive and emotional impacts, user experience, and iterative evaluation (e.g., Sutcliffe & Gault 2004; Cummings & Bailenson 2016; Schrepp, Hinderks & Thomaschewski 2017) were associated with "User Experience & Evaluation Metrics." Sources emphasising the integration of contextual data, such as cultural or environmental markers (e.g., AlFadalat & Al-Azhari 2022; Skov *et al.* 2013; Gonçalves *et al.* 2022), were mapped to "Contextual Data Integration." The proposed taxonomy thus reflects an inductive synthesis, with categories derived from the reviewed literature.

This taxonomy is intended to act as a guide in balancing different levels of realism, resource allocation and contextual data to achieve specific project goals. By referencing this table and the explanations that follow, designers can make informed decisions about how to implement either stylised realism or photo realism – along with varying content dimensions, data integrations and iterative feedback loops – to create VDCs that best serve each phase of the architectural process. Ultimately, this approach aims to enhance collaboration, support decision-making and deliver contextually authentic design experiences that align with the overarching objectives of this paper.

6.2. Description of key aspects

To begin, ***design context*** plays a pivotal role in determining the appropriate level of realism for any VDC. Early conceptual explorations tend to benefit from **stylised realism**, which simplifies geometry and materials to accelerate iteration and idea

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generation (Paes *et al.* 2017). As the design advances to mid-phase reviews, it may be helpful to integrate select **photo-realistic** elements to refine specific details while preserving efficiency (Doma & Şener 2022). For final presentations and stakeholder engagement, photo realism is often indispensable for conveying a high degree of credibility and immersion that facilitates clear communication of complex design intentions (Yu *et al.* 2022). Decisions around stylised or photo-realistic approaches also have implications for **resource allocation**: while stylised realism can minimise computational overhead and speed up workflows (Jerald 2015), photo realism offers visually convincing environments that might be critical for certain project goals – albeit at the cost of increased hardware demands (Stanney *et al.* 1998). Choosing the right balance between these two extremes avoids both underutilising the medium and overloading the system.

In addition, the VDC's overall sense of realism depends on a variety of **content dimensions** and factors, including visual fidelity, lighting, physics, avatar detail, soundscape, haptics, scent cues, interaction mechanisms and camera settings (Tavinor 2021; Gonçalves *et al.* 2022). Designers can carefully tune each of these elements to achieve the required degree of immersion or cultural authenticity (Heim 2000; Slater 2009). Projects emphasising local heritage, for instance, might include site-specific lighting effects and environmental audio, whereas early-phase conceptual tasks may strip away such details to focus on broad spatial relationships (Zheng 2022). **Implementation strategies** similarly shift according to project needs. Stylised realism implementations might work best during early or exploratory phases where swift iteration is prioritised (Jerald 2015), while photo realism implementations may become more relevant for late-stage reviews or final presentations that demand high-impact visuals and granular details (Doma & Şener 2022). Matching implementation style to project stage thus helps optimise resource management and maintain design clarity (Cox *et al.* 2017).

A crucial element in **preserving authenticity** lies in the integration of contextual data, such as cultural markers, environmental factors and material properties (AlFadalat & Al-Azhari 2022). Whether embedding localised textures or modeling weather patterns, these design choices anchor a VDC in real-world conditions (Gonçalves *et al.* 2022). The result is a more believable, context-specific environment that supports place-based design decisions and fosters a deeper sense of user engagement (Skov *et al.* 2013). Assessing **user experience** through metrics like presence, perceived realism, emotional resonance and task performance would provide invaluable feedback for refining a VDC (Cummings & Bailenson 2016). For instance, if individuals struggle with navigation, designers may choose to streamline geometry, alter camera settings or reduce visual clutter (Stanney *et al.* 1998). These metrics ensure that user-centred considerations remain central to the design process, allowing teams to strike an appropriate balance between immersiveness and practicality.

Once built, a VDC could benefit greatly from an ***iterative refinement*** **process**, incorporating feedback from questionnaires, user testing and stakeholder input (Sutcliffe & Gault 2004). Through multiple revision cycles, designers can calibrate the level of stylisation or photo realism to match the project's evolving objectives (Heim 2000). Striking a careful balance between authenticity and efficiency helps prevent cost overruns or an overly complex environment that could overshadow core design concepts (Stanney *et al.* 1998). In terms of ***deployment***, a single VDC can be adapted for different audiences and purposes (Sherman & Craig 2018).

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During early internal brainstorming, minimalistic stylised layouts may expedite creative exploration, while high-fidelity photo-realistic models may be used to convince external stakeholders or clients of a project's feasibility and aesthetic value (Doma & Şener 2022). Educational and research contexts also stand to benefit from variable realism settings, shedding light on how fidelity influences design comprehension and cultural interpretation (Skov *et al.* 2013).

Lastly, establishing ***long-term development*** and standards is vital as VR technologies advance. Best practices become more defined over time, supported by input from cultural experts, psychologists and human-computer interaction specialists, thereby fostering more contextually nuanced VDCs (Gonçalves *et al.* 2022). This cross-disciplinary collaboration not only encourages consistent, high-quality outcomes but also ensures that the final designs align with community needs, user comfort and cultural authenticity (Yu *et al.* 2022).

While the taxonomy proposed in this work offers a structured framework to support the development of VDCs, it is important to recognise that it represents an initial step in a broader exploration. The taxonomy serves as a conceptual tool to guide design decisions in immersive virtual environments and opens up opportunities for further study across several key aspects, such as its completeness, practical utility, adaptability to different design stages and relevance for a diverse range of project types, user groups and cultural contexts. Continued empirical research will be valuable to understand how the taxonomy captures the complexity of context in architectural design, supports collaboration and stakeholder engagement and influences design outcomes and user experiences over time. In the following section, we focus specifically on the designer's experience, empirically evaluating how expert architects interact with, perceive and reflect upon the process of designing within VDCs shaped by this taxonomy.

7. Empirical evaluation: expert engagement with taxonomy-guided VDCs

This study incorporated an empirical user-testing phase involving expert architects. Twenty-four architects with at least 2 years of professional experience in design practice were recruited to engage in concept design tasks using VR headsets directly with VDCs developed according to the taxonomy's principles. During these sessions, participants undertook tasks within VDCs developed with *Stylised realism* and *Photo realism* (Table 1; Figure 3), providing structured feedback on their experiences. Participants were instructed to develop a quick conceptual design for two hypothetical projects: (1) a pop-up retail pavilion in a culturally sensitive religious neighbourhood and (2) a small community café in a contemporary urban district. Each task was aligned with the corresponding VDC's environmental cues. Participants had 20 minutes for each task and were asked to prioritise conceptual ideation, spatial reasoning, and contextual responsiveness. These design prompts were intended to simulate early-stage architectural thinking within contrasting virtual contexts.

The primary aim of the empirical experiment is to evaluate how well the proposed taxonomy supports expert architects in designing and experiencing context within VDCs. The analysis focused on how well the taxonomy-guided VDCs manage cognitive demands, facilitate contextual learning, and stimulate creative engagement. Through structured user feedback and comparative

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Figure 3. Equipment used and examples of VDCs developed for empirical testing. The top right image depicts a VDC designed with stylised realism, while the bottom right image illustrates a VDC created using photo realism. The grey structures in the pink area are the architectural concepts designed by the participants.

assessment of stylised realism and photo realism environments, the experiments aimed to reveal the taxonomy's strengths, limitations and capacity to support meaningful contextual exploration in conceptual architectural design. Data collection was conducted through the Cognitive Load Questionnaire (Leppink *et al.* 2013), and the Short User Experience Questionnaire (Laugwitz *et al.* 2008) to capture a comprehensive picture of how experts perceived and interacted with different types of VDCs developed through the taxonomy.

The experimental setup utilised a Meta Quest 3 VR headset (Figure 3), chosen for its advanced graphical performance, user-friendly interface and ergonomic design, thereby affording participants an immersive yet comfortable environment for architectural concept design tasks. Gravity Sketch software was employed to facilitate design activities, as its intuitive and organic interaction style, along with minimal training requirements, make it particularly well-suited to supporting concept generation in architectural workflows. Participants were instructed how to use the VR headset and software before starting the design task and VDC exploration. Task performance and screen recording were managed on a separate laptop using OBS Studio, which was used to systematically capture participants' interactions and activities within the virtual environment.

Participants performed two architectural design tasks within VR, involving design ideation for the two distinct architectural scenarios. Both scenarios were explored under two levels of environmental fidelity to examine how the stylised realism and photo realism may influence the effectiveness of VDCs on architectural concept design (Teimouri *et al.* 2024). Task sequences varied systematically among participants to minimise order effects and potential learning biases.

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Two VDCs were constructed with contrasting degrees of realism: a stylised environment representing a modern urban district and a photo-realistic environment representing a religious neighbourhood. Based on the taxonomy dimensions outlined in Table 1, the stylised VDC used simplified geometry and abstracted forms, with colours representing land use and function rather than realistic materials. It omitted material textures and ambient elements such as sun and sky, and included symbolic vegetation through abstract plant forms. No lighting system was applied. In contrast, the photo-realistic VDC incorporated detailed geometry, high-resolution materiality, realistic vegetation and natural lighting conditions including sun angle and ambient sky. Colours were derived directly from real-world textures, and the spatial configuration reflected architectural characteristics specific to religious neighbourhoods.

7.1. Cognitive load insights

7.1.1. Clarity of instructions and the VDCs

It is essential to demonstrate that neither the instructions nor the VDCs posed barriers, as high levels of confusion or complexity could confound the interpretation of other experimental results. If participants struggled to understand the task or navigate the virtual settings, it would be difficult to attribute their performance or learning outcomes to the qualities of the VDCs themselves rather than to extraneous difficulties. In this stage, analysis of cognitive load questionnaire responses revealed that both the instructions provided and the VDCs themselves were accessible and straightforward for expert participants. Scores for intrinsic load, which reflect the perceived complexity of the VDCs and the design tasks, remained consistently low across the sample (mean = 1.99/10; Figure 4), suggesting that participants did not find the virtual environments overly complicated or demanding. Similarly, extraneous load scores, which capture the cognitive effort associated with understanding instructions or navigating the system, were minimal

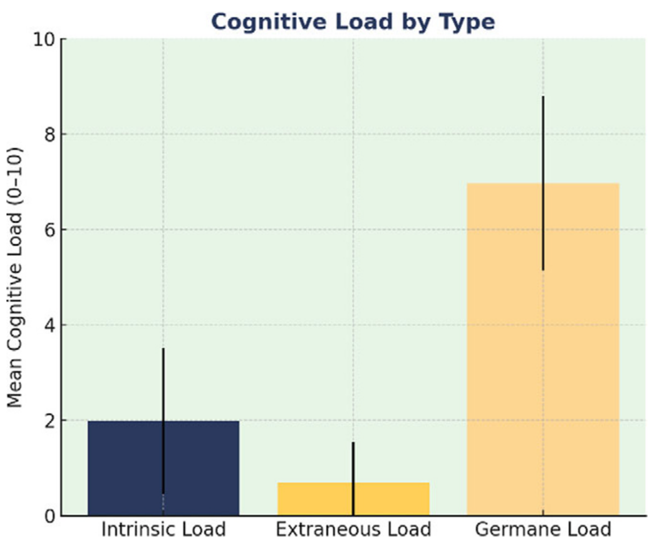

Figure 4. Cognitive load data visualisation.

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(mean = 0.69/10; Figure 4). The low levels of reported confusion, instructional difficulty or language ambiguity further support the conclusion that both the virtual environments and the study procedures did not create unnecessary cognitive burden. These findings suggest that the experimental setup was well-designed, ensuring that any subsequent insights or outcomes can be confidently attributed to the qualities of the VDCs themselves rather than to unrelated procedural issues.

7.1.2. Perception of context and learning outcomes

In contrast to the low levels of intrinsic and extraneous load, participants reported notably high scores for germane cognitive load (Figure 4), which is associated with meaningful learning and the development of new insights (Sweller, van Merriënboer & Paas 2019). To better capture the impact of the VDCs on contextual thinking, several items in the cognitive load questionnaire were specifically adjusted to focus on context-related outcomes. In addition to standard germane load questions, participants were asked to rate statements such as: "*The design tasks and virtual environments really enhanced my understanding of the contexts and design problem*," "T*he activity really enhanced my knowledge and understanding of designing in context*," "*The activity really enhanced my understanding of the design tasks and existing problems*," and "*The activity really enhanced my understanding of design problems and potential solutions*." The mean germane load score (6.97/10 – Figure 4) suggests that the VDCs were effective in fostering a deeper understanding of architectural context, problem comprehension, and solution strategies. These results suggest that, while the VDCs and instructions were unobtrusive, they simultaneously supported the acquisition of contextual knowledge and creative reflection.

7.2. User experience insights

To assess how different types of VDCs can influence designers' experience, participants were presented with both photo realistic and stylised VDCs and their experiences were evaluated using the User Experience Questionnaire (UEQ). The UEQ measures both pragmatic qualities (usability, support, clarity) and hedonic qualities (stimulation, inventiveness, excitement), providing a comprehensive profile of participants' subjective experience (Schrepp *et al.* 2017).

As shown in Figure 5, pragmatic quality scores – including perceptions of support, efficiency and clarity – were nearly equivalent between the two environment types, with only marginal differences observed. However, the hedonic qualities (encompassing dimensions such as excitement, interest and inventiveness) were rated substantially higher for the photo realistic VDCs than for the stylised realism. These results suggest that, while both approaches are effective in supporting practical engagement with design tasks, photo realistic VDCs may offer additional value by more strongly stimulating creative engagement and a sense of novelty.

These initial findings suggest that photo realistic VDCs may be particularly effective for fostering excitement, interest and a sense of innovation in expert architects, whereas both environment types are comparably effective with respect to usability and functional clarity. The only dimension where stylised realism was rated marginally higher was clarity, suggesting that simplified VDCs may sometimes enhance the legibility of the design context and proposals.

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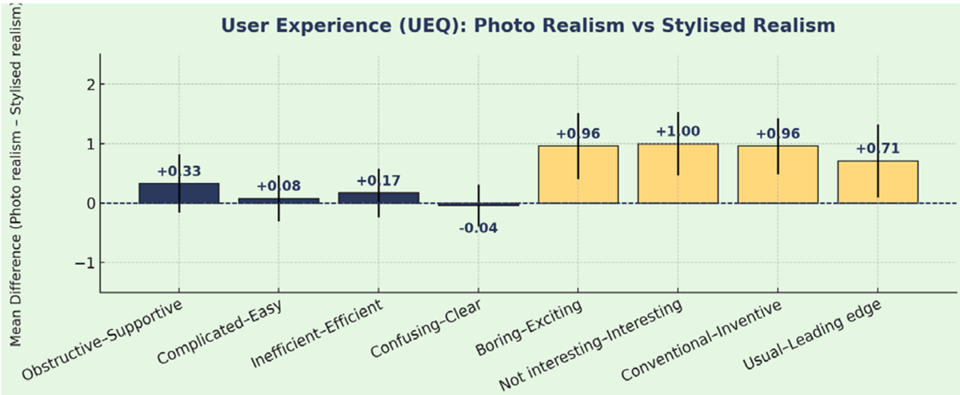

Figure 5. User experience differences between photo realism and stylised realism virtual environments (mean difference), with pragmatic (dark blue) and hedonic (orange) qualities distinguished. Positive values suggest a preference for photo realism.

7.3. Summary of empirical evaluation

The empirical findings of this study suggest that VDCs developed according to the proposed taxonomy are not cognitively overwhelming for expert architects. Instead, they provide substantial support for learning about context; an outcome that aligns with the core tenets of contextualism in architecture. Across the two different VDCs developed for this study using stylised realism and photo realism, participants reported low intrinsic and extraneous cognitive load, indicating that the complexity of the environments and the clarity of instructions did not hinder engagement. This allowed participants to focus more fully on exploring the spatial, cultural and historical dimensions embedded within the VDCs. In particular, the high germane load scores highlight that these VDCs effectively fostered meaningful learning, insight and the development of new perspectives related to site-specific design challenges. This empirical evidence hints at the potential of virtual environments to support the operationalisation of contextualist principles by providing immersive experiences that foreground the importance of context in the design process.

While both environment types were found to be usable and accessible, VDCs developed with photo realism were especially effective in driving excitement, creative engagement and a sense of innovation among participants. These high-fidelity environments enabled architects to experience context as "real" within the virtual domain, supporting deeper immersion and creative synthesis. Such outcomes suggest that VDCs, when thoughtfully crafted, can serve as "cognitive amplifiers," rendering contextual information more visible, tangible, and emotionally resonant. Importantly, this not only facilitates context-sensitive design thinking but also elevates the role of contextualism in contemporary architectural workflows. To ensure sustained impact, the study also points to the need for ongoing refinement of VDC usability and accessibility, so that the benefits of immersive contextual exploration remain available to a broader range of practitioners and stakeholders.

8. Limitations and directions for future research

While the current study provides initial evidence regarding the theoretical and practical significance of VDCs, it is not without limitations. Our empirical analysis

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primarily focused on perceived cognitive load, usability, and contextual learning among expert architects, leaving other critical dimensions, such as decision-making processes, long-term retention of contextual knowledge, collaborative interactions and the impact on actual design outcomes largely unexplored. The completeness and applicability of the taxonomy's factors and stages also remain to be empirically tested and systematically refined in diverse contexts. Notably, the present experimental protocol was unable to evaluate steps 7, 8 and 9 of the proposed taxonomy, which address the downstream impacts of design interventions, post-occupancy evaluation and the feedback of contextual data into future design cycles. These steps typically require extended observation of design implementation, real-world usage and iterative feedback over time; elements that were beyond the temporal and logistical scope of a laboratory-based user study. As such, assessment of these advanced stages will necessitate longer-term, practice-based research, potentially involving follow-up studies, in-situ deployment or integration with professional design projects.

Technological constraints, such as reliance on advanced hardware and software, and the subjective nature of presence and realism in VR, present additional challenges for broader adoption and generalisation. Future research may benefit from examining these issues by employing more diverse participant samples, including students, clients and stakeholders; utilising longitudinal research designs; and incorporating additional data sources, such as behavioural metrics, protocol analyses, and project-based assessments. Hence, the taxonomy could serve as a methodological framework for systematically developing VDCs for research purposes. For example, it could be used to create controlled variations in virtual context to study how different aspects of VDCs, such as realism, cultural markers or interactivity, impact cognitive dimensions of design thinking. Further investigation is warranted to evaluate how VDCs influence stakeholder engagement, cultural interpretation and the authenticity of context as perceived by various user groups.

9. Conclusion

As the exploration of VR-driven architecture continues to progress, the concept of designing in context is poised to acquire entirely new meanings. Where once "contextual design" was synonymous with physically traveling to sites, collecting photographs and using these resources to shape buildings back at the office, the future could entail wearing a VR headset and stepping directly into a richly rendered digital twin of a site. This shift underscores the growing importance of constructing robust VDCs: immersive environments that capture the spatial, cultural and historical characteristics essential to architectural decision-making.

In proposing a theoretical framework for creating these VDCs, this paper reveals how the relationship between psychological (subjective) realism and depictive (objective) realism can be strategically employed to bridge the gap between imagination and place-based knowledge. Photo realism and stylised realism offer complementary paths: the former ensures visual fidelity and precision for stages such as stakeholder presentations and final design reviews, while the latter provides a resource-friendly, creatively stimulating environment ideal for brainstorming and rapid iteration. While more empirical research is needed to corroborate these, this dual approach invites designers to alternate seamlessly between detailed simulations and more abstract, stylised representations, depending on the project's requirements, stakeholder needs or the specific design phase.

One of the most powerful implications of this approach lies in its capacity to cultivate deeper engagement between architects and the contexts they seek to enrich. Rather than passively referencing static imagery or relying on 2D plans, designers can "inhabit" a site – virtually perceiving light, scale and atmosphere – at any point during the design process. By enabling immersive contact with environmental, cultural and emotional dimensions, VDCs may support certain kinds of contextual reflection and decision-making; though this should be seen as a complement to, rather than a replacement for, real-world engagement. This ongoing dialogue between the real and the virtual promises a richer, more responsive architectural practice, one that acknowledges context as both a spatial and experiential phenomenon.

Addressing the core research questions, this study suggests that virtualising architectural design context is both meaningful and theoretically defensible, though not without potential challenges. The taxonomy developed herein provides a provisional but coherent framework for guiding VDC development, and empirical user testing suggests that well-designed VDCs can enhance contextual learning, creativity and immersion without overwhelming cognitive demands. Nonetheless, both the theoretical framework and empirical measures must continue to evolve through critical assessment, broader testing and methodological refinement.

Our theoretical work has been complemented by an initial empirical evaluation, in which expert architects engaged with VDCs developed according to the proposed taxonomy. The results of this user testing suggest that such environments are not cognitively overwhelming and, crucially, offer strong support for contextual learning – an outcome central to the aims of contextual architecture. Both Stylised Realism and Photo Realism VDCs were found to be usable and effective, with the latter particularly enhancing creative engagement and a sense of immersion. The empirical findings suggest that well-designed VDCs have the potential to act as cognitive amplifiers, making the context more visible, understandable and emotionally resonant, thus operationalising the principles of contextualism in a digital domain. At the same time, these findings highlight the need for ongoing refinement of both the taxonomy and the VDCs themselves, as well as for further research across diverse project types, user groups and cultural settings.

Despite its potential, however, this new paradigm also brings with it notable limitations. Chief among these is the reliance on the technological infrastructure that undergirds every immersive experience. Without robust hardware, stable software and carefully managed resource allocation, the high demands of photorealistic rendering and interactive simulations may overshadow the very design goals they aim to support. Smaller firms or educational institutions with limited budgets might struggle to adopt VR setups at the level of sophistication needed for nuanced contextual design. Additionally, not all project scenarios require highly realistic modelling – overly detailed or "busy" scenes might cause cognitive overload or diminish creativity, illustrating that more realism is not always better. Balancing technical constraints with conceptual vision is thus crucial, and choosing stylised realism over photo realism in certain phases may help mitigate these challenges. Another limitation arises from the subjective nature of presence and realism itself. Different users experience VR environments in varying ways; what

https://doi.org/10.1017/dsj.2025.10041 Published online by Cambridge University Press

feels profoundly immersive for one person may strike another as artificial or disorienting. Cultural interpretations can be equally diverse, meaning that a meticulously rendered VDC might inadvertently overlook local nuances or undervalue intangible aspects of heritage. Consequently, designers must remain vigilant, incorporating stakeholder feedback, community input and periodic on-site visits (where possible) to ensure that VDCs accurately capture the living qualities of a place rather than inadvertently reducing context to a static digital museum.

Looking ahead, as VR hardware becomes more accessible and the software pipeline continues to evolve, the boundary between "real site" and "virtual site" will likely blur further. The notion of "designing in context" may evolve to encompass parallel modes of engagement – physical visits and digital immersion – used interchangeably to achieve both practical and visionary aims. The significance of VR in architectural education will continue to grow, urging future practitioners to see immersive design as not just a novelty but a vital aspect of contextual thinking. Ultimately, the convergence of these trends suggests a future where site-specific nuances, creative freedom and technological innovation continuously inform one another, leading to architectural solutions that resonate more deeply with the identities and values of the environments they inhabit.

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