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A Phenomenological Framework of Architectural Paradigms for the User-Centered Design of Virtual Environments

Matthew E. Gladden

Institute of Computer Science, Polish Academy of Sciences, 01-248 Warsaw, Poland; matthew.e.gladden@gmail.com

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Abstract: In some circumstances, immersion in virtual environments with the aid of virtual reality (VR) equipment can create feelings of anxiety in users and be experienced as something "frightening", "oppressive", "alienating", "dehumanizing", or "dystopian". Sometimes (e.g., in exposure therapy or VR gaming), a virtual environment is intended to have such psychological impacts on users; however, such effects can also arise unintentionally due to the environment's poor architectural design. Designers of virtual environments may employ user-centered design (UCD) to incrementally improve a design and generate a user experience more closely resembling the type desired; however, UCD can yield suboptimal results if an initial design relied on an inappropriate architectural approach. This study developed a framework that can facilitate the purposeful selection of the most appropriate architectural approach by drawing on Norberg-Schulz's established phenomenological account of real-world architectural modes. By considering the unique possibilities for structuring and experiencing space within virtual environments and reinterpreting Norberg-Schulz's schemas in the context of virtual environment design, a novel framework was formulated that explicates six fundamental "architectural paradigms" available to designers of virtual environments. It was shown that the application of this framework could easily be incorporated as an additional step within the UCD process.

Keywords: user-centered design; architecture; virtual reality; virtual environments; phenomenology; user experience; human-computer interaction; cyberspace; place

1. Introduction

1.1. Virtual Reality as an Immersive Interactive Experience

The defining traits of contemporary virtual reality (VR) technologies are the deep immersiveness and interactivity of the user experience that they offer [1,2]. "Immersiveness" means that the images, sounds, and other phenomena presented by a VR system are not perceived by a VR user as just another small source of stimuli present within the environment; rather, VR headsets, earphones, haptic feedback gloves, and other VR devices attempt to block out a user's experience of that ambient "real" environment and wholly replace it with the multimodal experience of a fabricated environment. Meanwhile, "interactivity" means that a VR user does not passively experience the virtual environment but can instead interact with and manipulate it, for example, by walking around to view objects from a different perspective; by moving, reshaping, or destroying objects; or by engaging in dialogue with the avatars of other human users.

The use of immersive, interactive technologies to facilitate the experience of a virtual world is nothing new: although the degree of immersiveness and interactivity that they offer is severely limited, long-established types of products such as novels, board games, paintings, and films can be understood as devices that help a reader, player, or viewer mentally experience a fictional "virtual world" [2–4]. However, specialized VR hardware and software generate much more powerful sensorimotor feedback loops by detecting and interpreting a user's movements and other behaviors in real time to determine what action the user is attempting to take within the virtual environment, instantaneously calculating how the environment should respond, and then providing appropriate sensory stimuli to create a convincingly interactive experience [5,6]. Thanks to such immersiveness and interactivity, VR users do not simply "look at" a virtual environment in the way that one looks at a painting; rather, they become a visitor who has the experience of temporarily "occupying" or "inhabiting" that virtual space.

1.2. The Potentially Harmful Effects of Poorly Designed Virtual Environments

As VR technologies become more sophisticated and are more widely employed in a diverse range of therapeutic, educational, professional, and entertainment contexts, it becomes more important to develop coherent and effective approaches to the design of the virtual environments that are accessed through such systems. This is especially true given the fact that even high-quality contemporary VR equipment and well-designed virtual environments can generate unpleasant or harmful effects for users such as "VR sickness" or "cybersickness" involving dry eyes, eye strain, headaches, sweating, muscle aches, nausea, or other physiological responses [7–12]. Use of VR equipment may also produce spatial disorientation that can lead to physical accidents, which can raise questions of legal liability for VR platform developers, especially if such accidents were foreseeable and preventable [13].

Moreover, research suggests that the experience of spending time immersed in virtual environments can not only be disorienting and sickness-inducing at a basic sensory and physical level [5,6], but may also induce psychological effects including anxiety or a sense of being trapped. Immersion in at least some types of virtual environments may potentially be experienced as something "frightening" [14–17], "oppressive" [18–20], "alienating" [20–23], "dehumanizing" [20,24,25], or "dystopian" [26–28].

1.3. The Role of Architecture in Negative Experiences of Virtual Environments

Although some of these negative effects might be caused or strengthened by "non-architectural" elements of the virtual experience such as the contents of specific social interactions with the digital avatars of other human users, some may potentially be directly attributable to the "architecture" of a particular virtual space itself. As early as the 1990s, researchers began to investigate the potentially negative impacts of certain types of architectural structures or approaches that can be employed when constructing virtual environments [29,30].

For example, addressing research conducted by Meehan et al. [31] and Blascovich and Bailenson [32], Madary and Metzinger [33] analyzed the implications of the manner in which stress could be induced in VR users by presenting them with "dangerous" architectural structures within virtual environments, such as an apparently deep pit into which VR users could easily "fall" if they stepped over the edge of a solid platform or fell off the side of a narrow bridge-like beam. Typically, the inclusion of stress-inducing architectural features within a virtual environment is done purposefully and with a VR user's consent, either as part of "exposure therapy" designed to treat an anxiety disorder, as part of a VR training simulation, or as part of a VR game where creating a sense of danger is a welcome part of the entertainment.

However, the fact that stress, anxiety, disorientation, and other potentially detrimental effects can be purposefully induced in VR users raises the possibility that they might instead be accidentally produced by poorly designed virtual environments whose inexperienced or unskilled designers had no intention of creating such an unpleasant user experience (UX). The limitations of contemporary VR technologies already create great challenges for the developers of immersive, interactive VR platforms; any flaws or missteps in the architectural design of virtual environments can further exacerbate the UX problems inherent in such technologies.

1.4. The Challenge of Employing UCD in the Architecting of Virtual Environments

1.4.1. Previous Applications of UCD for VR

Given these realities, it would appear that the principles and practices of user-centered design (UCD) can offer valuable tools for improving the design and user experience of virtual environments by optimizing their architecture. UCD has already been beneficially applied in the design of real-world buildings [34,35] as well as in the design of smart-home systems [36–39], which combines elements of conventional UCD for electronic devices with unique architectural considerations. Moreover, UCD practices have been applied to virtual reality in contexts involving the development of VR platforms for rehabilitation [40], access to medical images during surgery [41], training [42], battlefield visualization [43], and interfaces for virtual museums [44–46] as well as with the goal of employing virtual reality to facilitate user-centered design of other products [47].

1.4.2. Complications in Applying UCD to Virtual Environment Design

Nevertheless, complications can arise during the design of such platforms due to the fact that VR-based virtual environments: (1) are not populated by the same types of "matter", objects, and forces as the everyday physical world; (2) generate unique types of neurocybernetic sensorimotor feedback loops for users; (3) may allow forms of movement, social interaction, and engagement with and manipulation of one's surroundings that are not possible in the everyday physical world; (4) are not bound by the same "laws of nature" that apply in the everyday physical world; and (5) both allow and require their own unique architectural practices, techniques, and methodologies [2,48]. Due to such dynamics, novel challenges are encountered by engineers, programmers, architects, and artists who attempt to employ the established principles of UCD in the creation of virtual environments. This study focused on one challenge that arises in the middle of the UCD process, as described below.

1.4.3. Creating an Initial Design with an Arbitrarily Selected Architectural Paradigm

The typical process of user-centered design is an iterative cycle with several stages [49,50]; Figure 1 applies these stages to the design of a virtual environment. The cyclical nature of UCD's evaluation and redesign stages allows the virtual environment's designer to improve the initial design to the greatest degree possible, based on feedback from real test users or evaluation using "personas" [51,52].

However, every concrete design for a virtual environment is implicitly grounded in a particular approach to architecture. If a designer's initial design employs an architectural paradigm that is fundamentally inappropriate (given the stated goals for that particular virtual environment), then improving the environment's design through repeated evaluation and incremental redesign might yield a user experience that is as good as possible for a virtual environment of that architectural paradigm; however, the user experience might still fall far short of what could have been achieved had the designer chosen a more suitable paradigm to begin with.

Figure 2 illustrates this problem: if a designer is not aware of the full range of basic architectural paradigms that are available when designing a virtual environment, then—due to a lack of training, experience, or imagination—the designer might instinctively and unconsciously home in on just one familiar paradigm, as if it were the only option available. This creates the risk that the virtual environment that is ultimately produced will generate a suboptimal user experience, despite the incremental improvements that are later made to it as a result of feedback and evaluation.

In other words, if a particular architectural paradigm is arbitrarily chosen by a virtual environment's designer and an initial design is created, the UCD process will be able to guide the designer to a particular design within the "possibility space" [53] of all possible designs that represents one of many local optima of UX quality (i.e., the best UX possible for the given architectural paradigm); however, finding the *global* optimum would require the designer to consciously weigh the full spectrum of different architectural paradigms, select the most appropriate one, and then create the initial design for the virtual environment.

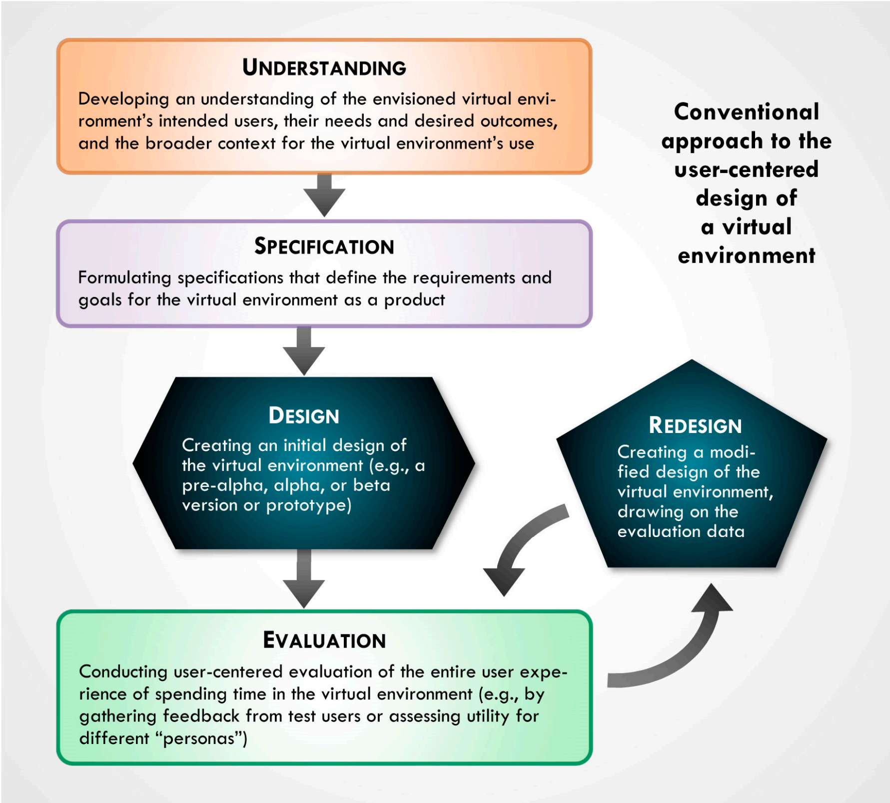

Figure 1. A conventional UCD process applied to the design of a virtual environment.

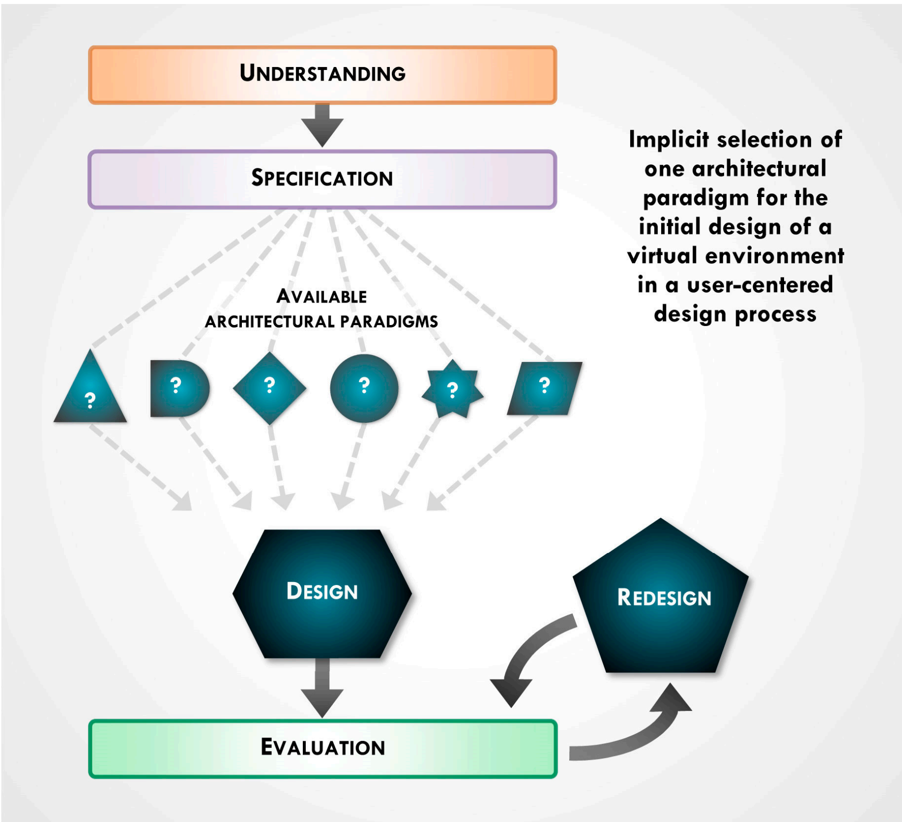

Figure 2. Creation of the initial design for a virtual environment often involves the unconscious choice of a particular architectural paradigm.

1.5. The Research Objective

Such difficulties could be reduced or eliminated if there were a mechanism within the UCD process that could expand, supplement, or prompt a designer's imagination by clarifying the full range of fundamentally different architectural paradigms that are available and then help the designer select the best one. To that end, the objective of this study was to formulate a conceptual framework that could support the designer of a virtual environment (and ultimately, improve the experience for its users) by incorporating an additional step into the UCD process to be performed after specifying the requirements and goals for the virtual environment, but before generating the initial concrete design. In this step, the designer will be led to (1) explicitly weigh a small but diverse range of distinct architectural paradigms according to which a virtual environment might be designed, and (2) select the paradigm that offers the best starting point for attempting to create a virtual environment that satisfies the chosen criteria.

If the number of distinct architectural paradigms included in the framework is too large, the process of explicitly considering them all will become unwieldy; if it is too small, the framework will not be able to robustly capture the full range of design paths available to a virtual environment's designer.

What Is Included in a Virtual Environment's "Architecture"?

In particular, when designing a virtual environment to be used by multiple individuals (e.g., for online gaming or workplace training), the social, political, economic, and cultural aspects of the virtual world are as important as its architectural structuring of three-dimensional space. This fact is implicitly recognized by contemporary definitions of architecture, which emphasize that "architecture" is not simply about the structuring of three-dimensional space by means of walls, doors, ceilings, and other physical elements; rather, it is about the structuring of a set of overlapping physical, geographical, existential, experiential, psychological, social, political, economic, technological, cultural, and ecological spaces that interact in complex ways [54–56]. While UCD can be applied to any such facets of a virtual environment, this study focused on UCD's application to the architecting of those aspects of virtual space that might be understood as geographical, experiential, psychological, and (from the perspective of a virtual environment's user) "physical" in nature.

2. Methodology

This study's methodology involved three elements. First, we analyzed a well-established framework for differentiating four fundamental architectural modes available to the designers of real-world architectural structures, in the form of the Heideggerian phenomenology of architecture developed by Norwegian architect and architectural theorist Christian Norberg-Schulz [54]. Essential elements of the fundamental real-world architectural modes presented in that account were identified and described. Second, by taking into account the unique possibilities for the structuring and experiencing of space in *virtual* environments and reinterpreting Norberg-Schulz's phenomenology in light of the process of designing such environments, a new framework was generated that explicated six fundamental "architectural paradigms" that are available to the designers of virtual environments. Third, a designer's activity of utilizing this new framework to purposefully select a particular architectural paradigm was integrated into UCD practice by proposing its inclusion as a concrete step that takes place at a particular point within the UCD process.

Within the spectrum of research methodologies discussed by Bryman [57] and Creswell and Creswell [58], the present study utilized an inductive approach, qualitative methodology, and phenomenologically based research philosophy, which can generate results with significant trustworthiness, credibility, relevance, and confirmability [59], if not the same type of "reliability" or "validity" pursued in positivist quantitative approaches [60]. The study relied on the collection, analysis, and synthesis of secondary data in the form of published scholarly texts and utilized a cross-sectional time horizon and purposive non-probability sampling method.

2.1. The Appropriateness of a Phenomenological Approach

Virtual reality attempts to create the (artificial yet convincing) experience of a particular world, while phenomenology offers a range of philosophical approaches that are especially attentive to our human experience of the world around us and our manner of being present in and interacting with that world [61]. It is thus not surprising that phenomenological methodologies have been found relevant and useful when analyzing or designing virtual environments. They have been used, for example, to develop Heideggerian explorations of VR focusing on the nature of truth, inauthenticity, the world, and aesthetic experience [62–64]; analyses of embodiment and intentionality in VR [65–69]; connections between the concept of the "lifeworld" and VR [2,70–73]; broader phenomenological aesthetic analyses of VR [1,74,75]; and more general phenomenological analyses of VR [76–79]. Norberg-Schulz's concept provides yet another phenomenological avenue for investigating the design of virtual environments.

2.2. Empirical Foundations of Norberg-Schulz's Architectural Phenomenology

Christian Norberg-Schulz was a leading member of the late-20th century movement of "architectural phenomenology," alongside figures like Jean Labatut, Charles Moore, and Kenneth Frampton [80]. Norberg-Schulz's phenomenology was theoretically and empirically grounded in his studies with renowned architects Walter Gropius and Mies van der Rohe, his close reading of Heidegger, and his years of experience as a practicing architect [81].

The phenomenological analysis of four real-world architectural modes that this study drew on was presented by Norberg-Schulz in his book *Genius Loci: Towards a Phenomenology of Architecture* (1980) [54], where it was empirically grounded in a comparative analysis of architecture ranging from the prehistoric megaliths of Malta and Stonehenge to the ancient structures of Egypt, Greece, and Jordan, to clay houses in Tunis and land demarcation practices in Japan, to the buildings of medieval France and Germany, 15th century Beijing, 16th century Istanbul, Renaissance Florence, and Art Nouveau Paris, to the urban architecture of contemporary Boston, Chicago, Milan, Moscow, and Sydney; the volume offered in-depth case studies of the landscape and architecture of Prague, Khartoum, and Rome. Norberg-Schulz's approach might thus be understood as a type of observation research [57] in which the whole world's settlements and buildings form the population and the particular objects analyzed by him constitute a purposive sample. Insofar as his phenomenology iteratively shaped and was shaped by his experiences as a working architect, it might also be understood as possessing aspects of grounded theory [57,58].

Norberg-Schulz's analysis may be critiqued on the grounds that despite its attempt to offer a universal anthropological account of architecture, it remains predominantly informed by European architectural practice, offering only brief references to, for example, the architectural traditions of South and East Asia. However, recent studies that have applied Norberg-Schulz's phenomenology in Asian contexts have affirmed his phenomenology's robustness, for instance, by using it to analyze the cultural landscape of ethnic communities in Indonesia [82] and the fictional garden that provides the setting for a classic Chinese novel [83]. The soundness of his phenomenology has been further supported by its use in fruitfully analyzing phenomena as diverse as urban design in Western countries and the Muslim world [84], the Catalonian landscape [85], the relationship of climate to Islamic architecture [86], contemporary harbor transformation projects [87], and Ancient Egyptian temples [88]; developing a photography-based phenomenological methodology [89]; and analyzing places described in works of poetry and literature [90–92].

2.3. The Relevance of Norberg-Schulz's Phenomenology to VR

Various aspects of Norberg-Schulz's architectural phenomenology have been applied to the analysis and design of virtual environments, including his account of the spatial organization and character of place [93], his theory of "existential space" [94], and his accounts of the differences between "place" and "path" [95] and between "place" and "space" [96]. However, this study's application of his account of the four fundamental modes of real-world architecture to the UCD of virtual environments is a novel approach.

3. Results

3.1. Analyzing Four Fundamental Modes of Real-World Architecture

In his Heideggerian phenomenological analysis of human-made buildings and settlements, Norberg-Schulz identified three architectural modes that represent unique approaches to the structuring of space, which he referred to as "cosmic," "romantic," and "classical" architecture, along with a fourth "complex" mode of architecture that combined multiple types. The particular styles of real-world architecture that have existed in diverse cultures throughout human history can be interpreted as manifestations of these modes, which are illustrated in Figure 3 and described below. Each mode manifests particular characteristics on two different planes of design, relating to (1) the way in which a whole city, town, or other settlement is organized in relation to the natural landscape, and (2) the way in which particular buildings and structures within the settlement are shaped and constructed.

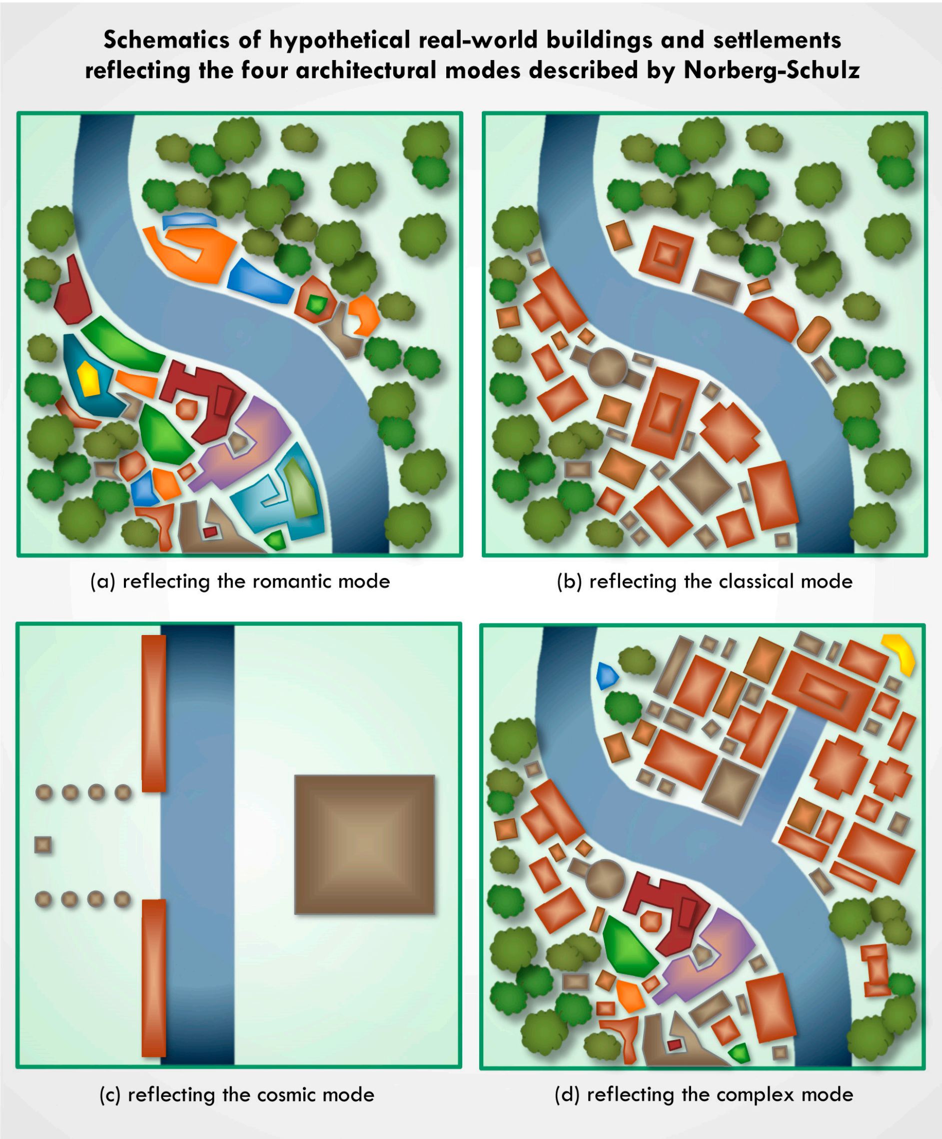

Figure 3. Norberg-Schulz's Heideggerian phenomenological account describes four basic modes of real-world architecture.

3.1.1. The Cosmic Mode

Cosmic architecture is exemplified in the buildings and cities of Ancient Egypt [54,97]. Places built in this mode appear not to have been consciously "composed" by human designers, but to make visible a "hidden order" that already existed within space. Structures are typically built from a narrow selection of simple, unornamented forms like cylinders, pyramids, and rectangular parallelepipeds. This mode deprives a place of expressivity, atmosphere, and dynamism and reveals it to be an environment in which human engagement and participation is not possible [54]. In cultures like that of Ancient Egypt, cosmic architecture manifests an absolute "pre-established order" that is not only spatial, but also political, economic, and social in nature [54].

Whatever little ornamentation exists takes the form of abstract geometric patterns that tend to "dematerialize" the volume of structures [54]. Cosmic architecture does not adapt the shape and orientation of its buildings to conform to the bends of rivers or slopes of hills; rather, it razes those natural features so it can impose its perfect geometrical grid on the landscape [54]. In its abstractness, cosmic architecture avoids humanizing and subjectivizing space; it reveals itself as something objective, pre-anthropic, and even pre-biological; it is the closest thing to pure space itself, before discrete elements within it have been identified and distinguished. Such architecture is totalitarian; it deals not in free and democratic expression but in the manifestation of mathematical necessity [54].

3.1.2. The Romantic Mode

For Norberg-Schulz, the romantic mode is exemplified by medieval Central European towns and Art Nouveau architecture [54]. Places built in the romantic mode structure space in a way that is topological and relational rather than strictly geometrical [54]. Such spaces are enclosed by continuous but irregular boundaries that do not correspond to simple, clearly determined geometrical shapes, and their contents are irregularly and asymmetrically distributed [54]. Romantic structures appear not to have been consciously planned but to have grown organically, like a living entity [54]. Such architecture adapts itself to the features of the local landscape, and its structures are thus closely linked to particular environments [54].

Even when such a space is carefully and purposefully designed, it appears "irrational" thanks to its profusion and variety of elements and the freedom and "wildness" of its ornamentation [54]. The variegation and ornamentation of romantic structures are accomplished not only through shapes, but also often through colors [54]. Romantic places demonstrate and facilitate expressivity: they possess a strong atmosphere shaped by contradiction and complexity; they may appear to be full of mystery, fantasy, and intimacy [54].

A contemporary manifestation of the romantic mode may be found in emerging types of biomimetic form-finding and parametric design, which use evolutionary algorithms and other forms of AI to generate curvilinear, asymmetrical, and dynamic architectural forms that resemble the smooth, active, mediating surfaces of living organisms and which would be difficult or impossible for any human architect to devise, given the limitations of human cognition [98–103]. Such biomimetic forms are often analyzed and interpreted using Deleuze's concept of the "fold" [104–106]; they might alternatively be understood using Ingarden's phenomenological model of the "relatively isolated system" [107,108], which draws on Bertalanffy's theoretical biology and concept of the open system [109–111].

3.1.3. The Classical Mode

Classical architecture is exemplified in the buildings and urban centers of Ancient Greece and the Florentine Renaissance [54]. The classical mode structures space in such a way that each individual building is consciously designed in a logical and geometrical manner that reflects an absolute spatial order; however, such units are grouped and arrayed in a loose topological manner that conforms to the natural features of the local environment. Such classical structuring of space manifests a certain "democratic freedom" [54] and purposefully links itself with "human qualities". As Norberg-Schulz explains, "In classical architecture the original forces are thus 'humanized', and present themselves as individual participants in a comprehensive, meaningful world" [54]; such architecture is presented to human beings in a way that is both immediate and intelligible [54]. Classical places thus readily create a sense of "home" for their inhabitants. They possess the sort of "imageability" [54,112] that allows human beings to both easily orient themselves within and identify emotionally with a given place [54]; this creates a sense of "belonging" that is experienced as something welcome rather than oppressive.

3.1.4. The Complex Mode

Norberg-Schulz observed that in practice, a building or city constructed by human beings usually employs a mixture of the three modes described above. He especially notes "the Gothic cathedral and the Baroque garden-palace" as examples of structures that synthesize more than one architectural mode [54]. The complex mode does not offer any content that is not already found in one of the three pure modes; however, its synthetic approach distinguishes it as a separate phenomenon. Such free synthesis of different modes is a key characteristic of architecture and urban design in the contemporary metropolis [54].

3.2. Formulating a Framework of Design Options for the Architecting of Virtual Environments

By drawing on Norberg-Schulz's insights and reinterpreting them in light of the unique possibilities and requirements for the structuring of virtual space, it is possible to identify six architectural paradigms that can yield different psychological impacts for the virtual "occupants" and users of places structured in such ways. Together, these paradigms yield a phenomenological framework that can be employed in the UCD of virtual worlds. These paradigms are illustrated in Figure 4 and described below.

3.2.1. The Cyberspatial Grid Paradigm

Here, the term "Cyberspatial Grid" is used to designate a conceptualization, design, structuring, and presentation of a virtual world that preeminently manifests what Norberg-Schulz would refer to as the cosmic mode of architecture. This paradigm constitutes one of the earliest conceptions of an immersive virtualized environment; it was foreshadowed in the simple geometry of early computer games like *Pong* [113], has been audio-visually depicted in popular films like *Tron* [114], and is reflected in some recent VR games [115–117]. The Cyberspatial Grid is the world of massive, regular geometric shapes, often parallelepipeds and pyramids. Their surfaces are either flat and undecorated or altogether absent, with the spatial extension of the shapes indicated only by glowing neon-like edges and corners (often with a monochromatic color scheme), creating the effect of a wireframe object positioned in an unlit, undifferentiated, empty space. Such environments often recall the look of early arcade game vector graphics. Features such as doors and windows existing at "human scale" [54] are often minimized or absent; structures appear not to have been designed by or for human beings but to be a manifestation of some non-anthropocentric, posthumanized [118,119], or even non-biocentric cosmic order.

The Cyberspatial Grid appears as something not "designed" or "grown", but "revealed" as an inherent facet of the universe. Such a place is dehumanizing and alienating; it does not allow visitors to identify with it or experience it as a "home." It is entirely geometrical: it excludes topology, because topology implies a relationship between distinct elements, and ultimately the only element in the Cyberspatial Grid is undifferentiated space itself.

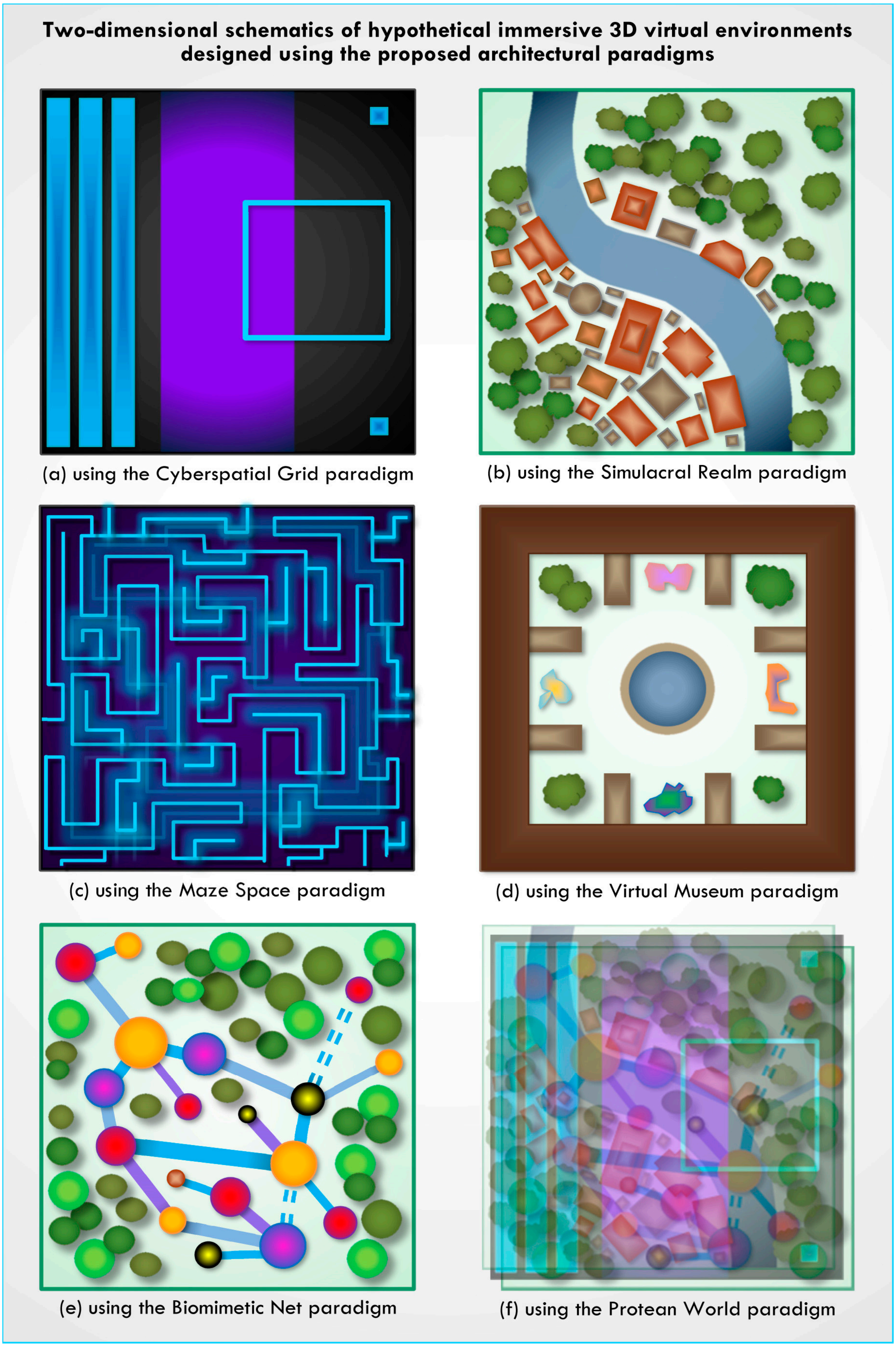

Figure 4. This study has proposed a framework of six architectural paradigms for use in the user-centered design of virtual environments.

3.2.2. The Maze Space Paradigm

Norberg-Schulz observed that the cosmic mode of architecture could sometimes manifest itself in a sort of inverted form: whenever the centralized state responsible for regulating such a space fails (or refuses) to reveal the universal order through its own building program, the environment remains chaotic and incomprehensible to its occupants; within such "labyrinthine space", the "inverted" form of cosmic architecture conceals the geometrical grid from view and eliminates any possibility of visualization and orientation by its human occupants [54].

In the context of UCD for virtual worlds, this inverted form of cosmic architecture warrants status as a separate architectural paradigm: it manifests itself as a "maze space" [120,121] that actively renders the ordering of space impossible and seeks to disorient, confuse, and trap the virtual visitor, as exemplified in some recent VR games [122]. While the Cyberspatial Grid appears as something perfect and static, Maze Space is maximally dynamic and unstable: taking advantage of the unique possibilities of virtual reality, it can reveal itself to visitors through walls that continually rearrange themselves, slowly shrinking spaces, infinitely extending hallways, invisible barriers, and doors that open into a different space every time they are opened. It creates an atmosphere as oppressive and alienating as that of the Cyberspatial Grid, but by different means.

3.2.3. The Biomimetic Net Paradigm

A contrasting conceptualization of the structuring of a virtual environment is that of the "Biomimetic Net"; it manifests what Norberg-Schulz would call the romantic mode of architecture. The Biomimetic Net is a virtual environment whose structure appears to have evolved and grown organically, like that of a vast biological neural network; it is a world comprising distinct nodes that are linked quasi-synaptically. The Biomimetic Net is a structure (or agglomeration of structures) that is dynamic, continuously changing, and perhaps even experienced as something "living" and sentient. Its structures are arranged in organic patterns; its elements interact in the "wild" and unregulated manner of organisms within a natural ecosystem. One orients oneself within and navigates the Biomimetic Net not through the use of absolute spatial coordinates, but in relation to the topological arrangement of its nodes and their connections.

Although the paradigm of the Biomimetic Net has long existed—inspired by the development of early computational models for artificial neural networks [123–126]—it has been given new impetus by recent scholarly reflection on the possible future emergence of a "sentient Internet" that spontaneously arises through the interaction of its billions of networked components with their environment [119,127–131] in a manner resembling the evolution of biological life. In some ways, the growing prevalence of the Biomimetic Net as a paradigm mirrors the rise of the Internet, online social networks, and the Internet of Things [132,133]; conceptualizations of networks as quasi-biological have also become more common as increases in computer memory and processing power have made feasible more sophisticated visual depictions of virtual environments employing curvilinear, dynamic, and biomimetic forms rather than simply static grids. Such imagery has been presented, for example, in some manga [134], anime [135], and recent VR games [136].

3.2.4. The Simulacral Realm Paradigm

The fourth conceptualization is that of the "Simulacral Realm", manifesting what for Norberg-Schulz is the classical mode of architecture; its name is used here in a sense that can be compared with but is not identical to the understanding of "simulacra" found, for example, in Baudrillard [137] or Deleuze [138]. The Simulacral Realm reveals itself in a virtual environment offering such robust sensorimotor immersion, sophisticated cybernetic feedback loops, and detailed and "realistic" depictions of its rich and varied contents that a human being granted access to such an environment via a VR system can potentially become an "inhabitant" or "dweller" in a meaningful sense of the word; such a Simulacral Realm can be experienced by human beings as a true "home".

The Simulacral Realm may attempt to provide an accurate simulation of the real world, or it may fashion an imaginary yet fully believable depiction of a world that does not exist as an analogue physical reality, such as a pseudo-medieval realm of the sort prevalent in fantasy literature. Such a Simulacral Realm often includes some form of built human settlements that are distinguishable from their surrounding "natural" environment and which have ostensibly grown organically over an extended period of time, even as the individual buildings or structures within them are depicted as having been purposefully designed and constructed at particular times. Such Simulacral Realms have been visualized in literary works [139], films [140–143], and contemporary VR computer games [144].

3.2.5. The Virtual Museum Paradigm

The paradigm of the Virtual Museum can be understood as an inverted form of the Simulacral Realm: while the classical mode of architecture imposes geometrical order on individual objects but allows them to be topologically arranged in a free and organic manner, the Virtual Museum acquires a diverse array of elements that each possess their own unique internal dynamic and "life" and then forcibly arranges them in a rigidly ordered geometrical manner. For visitors, it can create the atmosphere of a gallery upon whose plain, regular, rectangular walls rich, living forms are being displayed and appreciated; a warehouse where they are "stored"; or a prison where they have been "confined." Among VR-enabled museums and exhibitions [145–148], some but not all employ the Virtual Museum paradigm; conversely, the paradigm can be used to create many types of virtual environments that are not literally meant to function as "museums."

3.2.6. The Protean World Paradigm

The sixth conceptualization of virtual structure is that of the "Protean World," manifesting what Norberg-Schulz describes as complex architecture. In the real world, a single contemporary building or city often combines elements of cosmic, romantic, and classical modes by displaying them at the same time in different geospatial regions. While a single virtual environment can also manifest itself alternatively through different paradigms, the experiences of these paradigms are often separated temporally rather than spatially: a single human visitor may, for example, perceive a single virtual environment's structure as a Cyberspatial Grid in one moment but later as a Biomimetic Net.

The different paradigms described above may thus be employed as alternative "graphical user interfaces" or "skins" for mapping a single underlying digital-physical structural reality to different sets of sensory input, with transitions between the GUIs either selected by a human user or controlled by the VR system [48]. Conceptualizations of such Protean Worlds can be found in diverse works of science fiction [134,135,149,150] in which a character immersed in a virtual environment can experience it at different times according to different paradigms, depending on which of those paradigms best matches the character's—or the virtual environment's—current operational needs or preferences.

3.3. Incorporating the Framework of Design Options into the UCD Process

The framework developed above can be incorporated into the UCD process for architecting a virtual environment by inserting a step after the specification of the environment's requirements and prior to the creation of the environment's initial design by the designer, as illustrated in Figure 5. Before attempting to fashion a concrete initial design for the virtual environment (which will necessarily employ one or more of the paradigms, whether the designer is aware of that fact or not), the designer can analyze the specifications and compare them with the six architectural paradigms offered by the framework. The designer can then purposefully select the paradigm whose characteristics appear to offer the best path for the design of a virtual environment that can elicit the desired user experience.

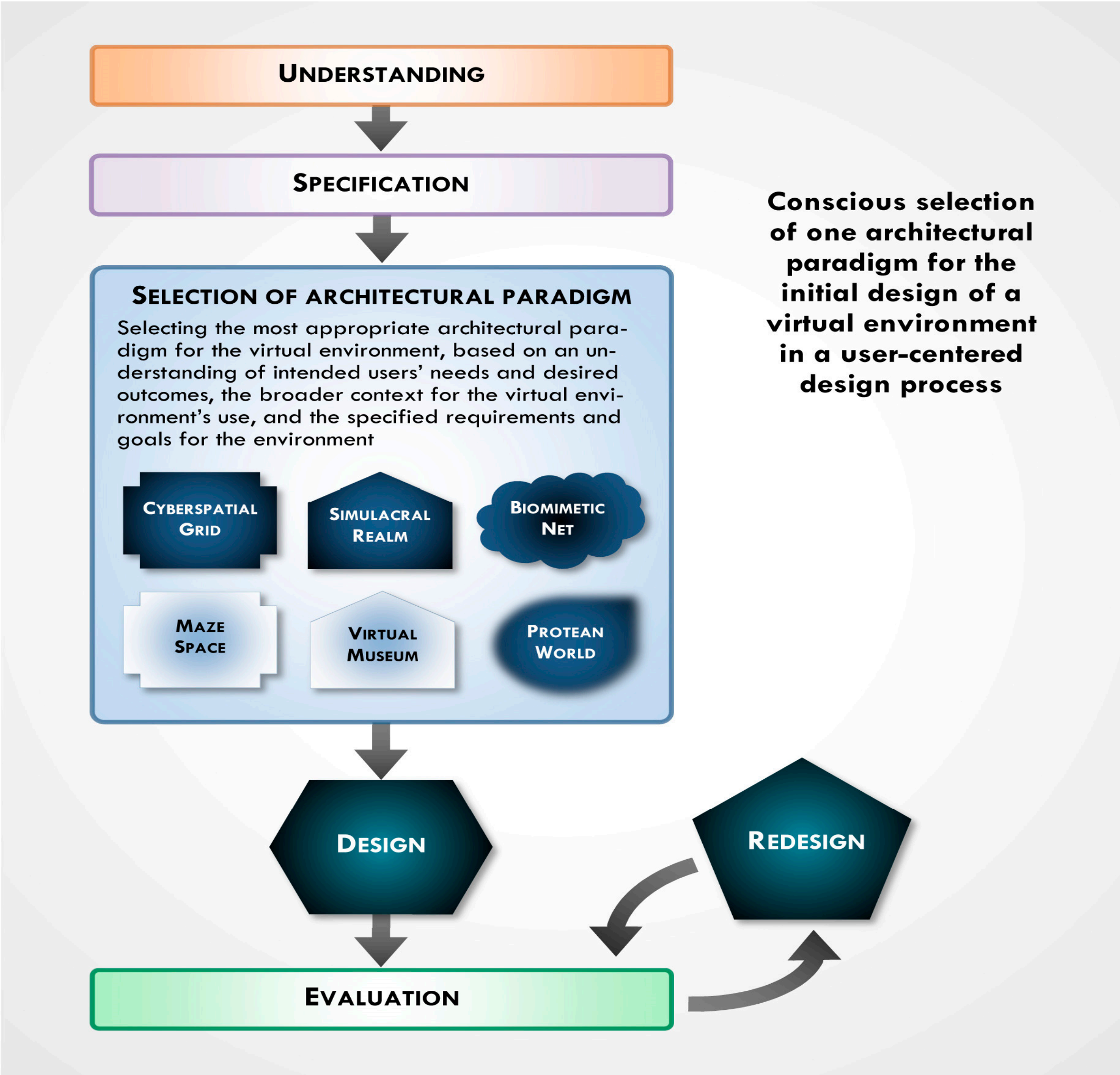

Figure 5. The proposed process of UCD for a virtual environment adds the explicit step of selecting an appropriate architectural paradigm.

Alternatively, the framework can be employed to at least ensure that the designer does not inadvertently choose an architectural paradigm whose characteristics are grossly incompatible with the stated specifications and are unlikely to allow the design of an environment that facilitates the desired user experience.

4. Discussion

4.1. Implications for the Design of Virtual Environments as Products

Imagine, for example, that a designer has been charged with creating a virtual environment for use in a science-fiction-themed VR game that is meant to conjure up in players feelings of awe, fear, and intimidation as they explore an abandoned settlement of some unfathomably powerful, ancient, and logically-minded alien civilization: use of the framework developed in this text would suggest that a designer might reasonably employ the Cyberspatial Grid paradigm when architecting the initial version of the environment to be evaluated and refined through later stages in the UCD process. On the other hand, consider a designer who has been charged by a large multinational corporation with developing a VR-based online "virtual campus" meant to bring together employees from around the world for business meetings: if the space is intended to make workers feel "at home" and to strengthen their sense of identification with their employer, then the proposed framework suggests that the designer might utilize the Simulacral Realm paradigm when crafting the initial design for the environment.

The framework might be similarly applied, e.g., in the design of VR-based virtual shopping malls, offices, art galleries, theaters, museums, libraries, training facilities, educational venues, lounges, meditation centers, gardens, vacation spots, or sports facilities or in VR-based games or works of interactive fiction. Figure 6 provides an overview of how the framework might function in such design tasks.

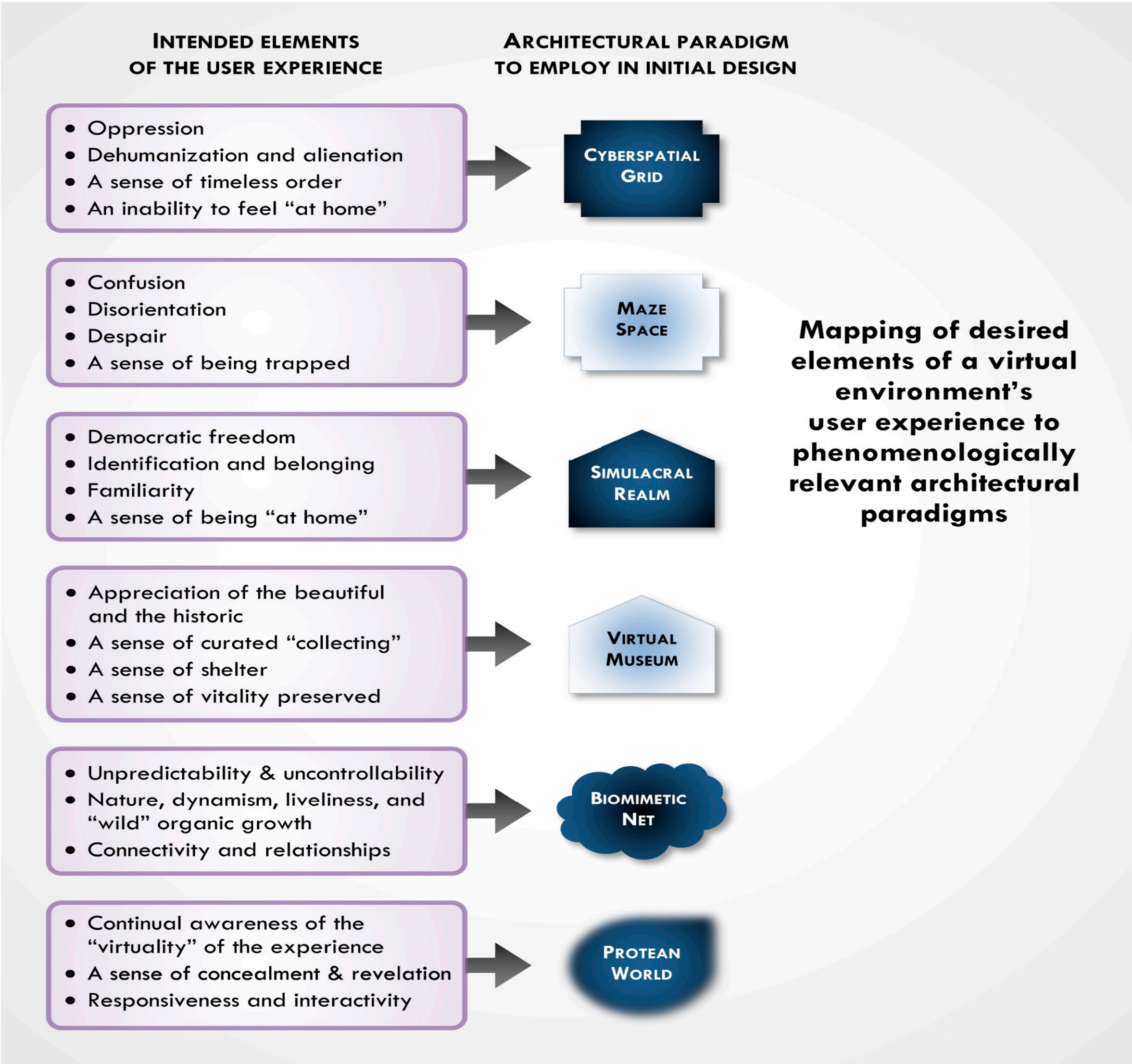

Figure 6. Use of different architectural paradigms can be expected to yield virtual environments that generate different types of user experiences.

4.2. Is The Proposed Framework Truly "Architectural"?

The question may be raised of whether the proposed paradigms are truly "architectural" in nature (rather than more loosely "artistic"), as virtual structures designed in accordance with them might, for example, comprise an exterior skin but no supporting interior infrastructure, or possess floating or continuously shifting elements that behave in ways that would be impossible for architectural structures existing in the everyday physical world. However, Ingarden contends that from a phenomenological perspective, the true "building" is not a heap of physical matter existing in the world (which is not inherently differentiated from its surrounding environment or distinct from other "non-building" heaps of matter), but the purely intentional object constituted in the minds of the human beings who experience and recognize a particular object as a building and use it as such [110,111,151]. While such a purely intentional "building" might be grounded in a physical ontic foundation in the form of a large parallelepipedal shell of stone, glass, or brick, it might instead be grounded in a physical ontic foundation in the form of a VR system's hard drive and the array of photons emitted by its headset's display screens [2,151,152]. Similar interpretations are offered by the phenomenologically grounded French school of Architecturology, which conceptualizes architecture not as something primarily relating to physical construction or decoration but as a cognitive activity [153]; such activity might conceivably involve the mental structuring of "real" or "virtual" space.

4.3. Implications for Research Involving Virtual Reality

The possibility that immersion in virtual environments manifesting different architectural paradigms might generate different psychological effects presents both challenges and opportunities for scientists who employ VR as a research tool. For example, the results of empirical studies into psychological phenomena obtained by studying the immersion of individuals in virtual environments of a certain architectural paradigm may or may not apply to immersion in environments with different architectural paradigms.

If researchers are unaware of distinctions between such paradigms, they might mistakenly attribute certain psychological or physiological effects to "immersion in a virtual environment", whereas in fact, the effects are due not to immersion in virtual reality per se, but only to immersion in an environment architected using a particular architectural paradigm. If researchers consciously select a specific paradigm when crafting their virtual experimental environment and explicitly identify that paradigm when publishing their results, it would make it easier for other scholars to interpret the findings and attempt to replicate the experiment.

4.4. Ethical Implications

On one hand, the framework formulated in this text provides the designers of virtual environments with a new tool to support ethical design: by carefully selecting an architectural paradigm, designers can more easily avoid unintentionally placing users in disorienting, stressful, frightening, or embarrassing situations. At the same time, though, new ethical challenges may arise as unscrupulous designers who (for whatever reason) wish to create oppressive, dehumanizing, or harmful virtual environments might potentially employ such tools as a means of more effectively manipulating users' moods, anxiety levels, or other physiological responses to that end.

4.5. Directions for Further Research

This work focused on (a) elaborating the theoretical basis for the purposeful selection of architectural paradigms when carrying out the UCD of virtual worlds, and (b) formulating a conceptual framework that could guide further study of that process and enhance the awareness on the part of VR designers of the architectural paradigms available to them. While the empirical foundations of Norberg-Schulz's architectural phenomenology are generally well-documented, future empirical studies might now be designed more particularly on the basis of this work to support, refine, or challenge its proposed framework for informing the design of virtual environments, for example, by testing VR users' responses to environments architected according to the paradigms described here and measuring the differing psychological impacts (if any) produced by those paradigms.

5. Conclusions

A virtual environment based on a flawed or inappropriate architectural approach may generate psychological effects in visitors that undermine the desired user experience. It is hoped that by "priming" the imagination of designers and leading them to more consciously select the most appropriate architectural paradigm, the framework presented in this study can facilitate UCD processes that yield virtual environments that elicit the types of experiences that will be of greatest utility, meaning, and value for their users.

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