virtual worlds

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Essay

The Impacts of Online Experience on Health and Well-Being: The Overlooked Aesthetic Dimension

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Abstract: It is well-recognized that online experience can carry profound impacts on health and well-being, particularly for young people. Research has already documented influences from cyberbullying, heightened feelings of inadequacy, and the relative decline of face-to-face interactions and active lifestyles. Less attention has been given to the health impacts of aesthetic experiences of online users, particularly gamers and other users of immersive virtual reality (VR) technologies. However, a significant body of research has begun to document the surprisingly strong yet previously unrecognized impacts of aesthetic experiences on health and well-being in other arenas of life. Other researchers have used both fixed laboratory and wearable sensors and, to a lesser extent, user surveys to measure indicators of activation level, mood, and stress level, which detect physiological markers for health. In this study, we assessed the evidence that online sensorial experience is no less important than in the physical world, with the capacity for both harmful effects and salutogenic benefits. We explore the implications for online design and propose an outline for further research.

Keywords: virtual world; virtual reality; augmented reality; immersive environment; visual appeal; healing environment; therapeutic environment; beauty

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1. Introduction

1.1. From Negative to Positive Impacts on the Health of Online Users

There is currently a growing concern about the potential negative impacts of online experiences on health and well-being, particularly for young people. Among the topics well-studied in the literature are cyberbullying [1], heightened feelings of inadequacy, depression and even suicide [2], and the decline of active lifestyles and healthy face-to-face interactions [3].

There has been less consideration of the potential *positive* impacts of online experience on health and well-being, which is the subject of this paper. In particular, there is emerging evidence of the salutogenic (health-promoting) benefits of certain classes of aesthetic experience, including the experience of structures perceived by the user as beautiful. While the existing literature focuses on naturalistic and urban experiences, there is growing evidence that online experiences can have a similar positive impact.

In this paper, we explore the potential for positive health effects from experiencing aesthetically beautiful virtual worlds. Given that much of the current focus in interface design has been on usability rather than beauty, there is definite room for discussion on

the topic of aesthetics. Even within game design research, there has been little discussion on beauty in game worlds when it might be expected that game worlds that feel beautiful might encourage engagement and a sense of wonder. In addition, there is an important opportunity for aesthetic exploration and refinement of the user's capacities for aesthetic discernment. This contrasts with the potential for passive consumption of crude but exciting aesthetics, resulting in atrophy of the capacity for fine aesthetic discernments. This issue is treated here using a pragmatic approach that draws on results from environmental psychology, biology, and mathematics.

1.2. Shared Aesthetic Judgments and Healing Environments

Furthermore, while there is undoubtedly a socially constructed component of what is perceived to be beautiful, emerging research shows that there are also structural characteristics that are widely shared among different populations (as we will explore in more detail herein). The result is a widely shared set of aesthetic judgments from which a smaller subset of differentiated judgments arise from individual variations and social constructions. Evidence suggests that our widely shared judgments are rooted in our common human evolutionary history, particularly the experience of natural environments, plants, and animals (the so-called "biophilia effect").

The research has documented both positive or "salutogenic" health impacts (from visual experiences judged as beautiful) and negative or "pathogenic" health impacts (from over-exposure to visual experiences judged as ugly and/or stressful). The implication is that designers have a responsibility to provide a basic background structure of salutogenic or health-promoting visual experiences, on which they may choose to create more transitory moments of excitement, stress, or even ugliness.

We, therefore, propose a normative standard for designers to provide a universal visual experience arising from a persistent background of biologically based objective beauty, which continues to be a key ingredient of the natural settings in which our ancestors evolved. It is notable that artificial environments maintained this background effect until the 20th century, after which it was progressively damaged so that it could no longer be relied upon for emotional nourishment. For that reason, it is necessary to re-assess and re-establish this normative standard.

Inherited misunderstandings complicate the creation of genuinely healing environments in the current physical world through commercial processes; a far easier option is to design virtual worlds that embody healing properties, and perhaps this sensibility can later carry over into the physical world [4]. Having positive experiences in virtual worlds triggers salutogenic emotions and unconscious bodily responses in all people, whether they do or do not suffer from any psychological issues [5]. To gain a health benefit, the design of the virtual world should mimic the natural world in a way that induces the biophilic healing effect that comes from plants and special geometries [6–12].

All of these findings point to new opportunities for designers of online experiences and virtual worlds and new ways to meet the needs of online users (including children and other vulnerable populations). The findings also point to the harm that can be done to users and the professional responsibility that online designers, like all designers, owe to their users.

A well-designed virtual experience provides a healthy escape for persons who live in industrial/modernist cities that, as they are built according to currently accepted standards and typologies, have negative effects on their occupants [13]. Those effects are unconscious and lead to anxiety that accumulates over time [14]. Since our society does not usually discuss such low-level persistent mechanisms, they are not consciously perceived by those who are affected. The only clue is a chronic feeling of discontent and general malaise. Periodically, resentment coming from the geometry of the built environment that a sector of society inhabits because of socio-economic constraints can explode into social discontent [15,16].

This is a basic question of public health, not aesthetics per se. Multiple factors affect human health, yet many of them are not sufficiently recognized. Separate from obvious biological and chemical factors, the physical/visual complexity of our environments plays

a much larger role in human health and well-being than is usually acknowledged. An environment that the human body perceives as being "alive" in some direct (but hard to pin down) sense helps to trigger positive-valence physio-psychological responses. Over time, this response influences the users' state of health positively (otherwise, environment-induced anxiety generates pathologies) [17].

1.3. Christopher Alexander's "Living Structure" Versus Copying Images

In this discussion, we refer to the work of the architectural theorist Christopher Alexander, whose description of the preferred geometry of place as a "living structure" is not a single and unique state but a complex, multi-scale, multi-category phenomenon (and not only a visual one) [18]. It is important to avoid the reductionist trap of a "silver bullet" or a single solution to the problem of design, which in any case, is always bounded by our own rationality and the limits of model-making. (We could link this point mathematically to a fundamental "incompleteness", as Gödel and others defined it.) To create a "living structure", we need to go through iterations and feedback and gradually evolve healthier and more whole environments.

In previous generations, technological society made the mistake of taking a "silver bullet" approach with narrow criteria, e.g., sanitation, thermal comfort, or access to fresh air and light. These factors are important, but there are many other levels, including the capacity of the distributed agents to make their own evolutionary adaptations. These solutions are contingent upon the capacity of designers and planners to empower them to do so, something woefully neglected in a reductionistic approach. That is what occurred for much of the 20th century, and those standardized design typologies dominate the present day's buildings and cities. As discussed later in this essay, the generative and adaptive nature of Alexander's work versus the industrial/modernist framework emphasizes this point very well.

If we look at, say, the 1926 Dessau Bauhaus and 1927 Stuttgart *Weissenhofsiedlung* building prototypes and the 1933 Athens Charter, they are all about these narrow criteria to be copied superficially as images [19]. Those images—highly "innovative" at the time—were introduced as promises of a healthier and more socially just future. When we built places like this in the past, they failed miserably (e.g., the US "projects", the UK "tower blocks", the Paris "banlieues", etc.). Those environments created according to a reductionistic set of design rules failed to provide for the "organized complexity" and the adaptive capacities of people, the opposite of working with the evolutionary patterns of history and nature.

1.4. AI and Beauty That Evolves through Selection Criteria

Adaptive design is not an act of imposition—despite architectural academia teaching it as such for decades—it is a process, an evolution subject to selection criteria of human adaptation and use. Missing that essential point turns design into a dangerous abstraction. You cannot just apply one narrow mathematical attribute of design and think that it will deal with everything. While true, as far as it goes, this fundamentalism overlooks that there are important and overlooked attributes, without which we are really pursuing a dead end when it comes to healthy human environments!

Given recent developments in artificial intelligence (AI), the question arises of whether virtual worlds generated by AI may spell the end of humans exploring beauty, how to create it, and how to use it to nourish us. Exploring, creating, and using beauty only come about when people discover for themselves how to be human. Many AI implementations at present (e.g., social media news feeds, algorithmically served ads, generative AI content) effectively outsource beauty to machines, and the algorithms push their own selected feed onto children and adolescents, including aesthetic content. This process disempowers individuals who cannot exercise their own natural judgment or develop that capacity in a healthy way. Human beings are Homo faber—"man the maker"—and the present state of affairs discourages and disables people from making. The corporate provider of aesthetic experiences (meant to manipulate but not to nourish) profits by creating unhappiness and even distress in the users. But this situation

is not new to the 21st century; it has been underway since architects in the early 20th century embraced the industrial-modernist aesthetic.

2. Methods and Analysis—Outline of This Essay

The present study collects and relates results from disparate disciplines into a framework for improving the salutogenic experience in virtual worlds. We document and highlight relevant information in the following sequence.

Section 3 summarizes what is known about aesthetics and health outside of the online world, in the discipline of biophilia, etc. This material provides the evidential basis for assessing healing online environments. Section 4 lists in detail what is known about health impacts in the online world. Beginning with the influence of games that provide a visceral experience (Sections 4.1 and 4.2), we introduce the notion of "living structure", following Christopher Alexander (Section 4.3). This section discusses "design patterns", also introduced by Alexander, as documented reusable solutions for achieving adaptive design. It is this "living structure" that is largely responsible for salutogenic effects in both physical and virtual environments. Various design trends have eliminated living structures from the environment, for example, the monotonous repetition that is falsely assumed to be an indispensable feature of industrial production (Section 4.4). However, uniformization and lack of variety have negative consequences, and in some cases, the induced visual stress leads to headaches. Section 4.5 establishes the connection to aesthetics online and in VR worlds. But the point we underline is the absence of beauty in digital design, which could be attributed to several reasons: the lack of teaching resources on how to generate beauty and the confusion that equates an abstract conception of beauty with mechanical efficiency.

Objective beauty in physical architecture is due to specific aesthetic properties and their importance (symmetry, etc.). Design rules for generating objective beauty rely heavily on Christopher Alexander's work on aesthetics and environmental structure (Section 4.6). Designers of virtual worlds naturally copy both design methodology and specific designs from the real world, but this can have opposite effects depending upon whether it satisfies or violates criteria set by Alexander. This section discusses the Roku City screensaver as an example of a viscerally attractive virtual world and explains the design features responsible for its appeal.

Section 4.7 mentions how the new Apple Vision Pro headset combines mixed reality in a way that seems to conform intuitively to our own discussion. One of our principal aims is to introduce virtual worlds as therapeutic settings, a project that has been initiated by various groups. The ability to use real-time feedback from physiological monitors to evolve the appearance of a virtual environment opens the door to promising new results on the geometrical foundations for potential "healing worlds" (Section 4.8).

The resulting synthesis of data from different disciplines presents a picture of the potential salutogenic (healing) benefits of virtual worlds, but only if they are designed to incorporate very specific geometrical and sensory characteristics. One possible surprise of our investigation is that simply porting architectural design from the physical to the virtual worlds does not necessarily accomplish the required goal, and we detail why this is so. It is mentioned here how tourist attractions—mainly of historical buildings and urban fabric—give clear hints on how to design healing environments (Section 4.9).

Section 4.10 suggests the need to apply design validation to the virtual environment. Surely, a world that people will spend a lot of time in needs to be assessed for its effects on human health. This methodology comes from the procedure for testing medical equipment and software, where a rigorous checklist is imposed by the U.S. Food and Drug Administration. Nothing like this exists in current architectural practice, while education does not prepare students to conduct any kind of scientific analysis.

Section 5 discusses the broad implications of beauty in virtual worlds, summarizing previous work on analyzing the design of the metaverse. We postulate the search for objective beauty in virtual worlds to be a key factor for users, especially as so many of them inhabit physical environments that lack the necessary emotional "background of visual beauty" almost entirely. Here we reference the philosophers Martin Heidegger and Gaston

Bachelard on the characteristics of what is perceived as "comfortable" settings, a space where humans can truly feel at home.

There is an enormous amount of recent research on what makes an environment comfortable to experience based on medical feedback and not aesthetics. Section 6 collects our ideas on which topics need to be pursued with research agendas. As the contribution comes from different effects, the effort needs to combine and coordinate multiple channels of investigation. Section 7 summarizes some psychological factors for appreciating beauty and applies the five-factor model to identify personality types that can profit from beauty in virtual worlds.

Artificial intelligence (AI) is evolving in parallel to virtual worlds, and some important findings on the appearance of objective beauty apply here (Section 8). We summarize recent applications of both verbal and visual AI programs to identify objective beauty, where the results point to what we already know from scientific analysis. Namely, that biologically based beauty is contained more in traditional design rather than industrial-modernist design. These results raise a warning flag to invite conventionally trained architects to design virtual worlds. At the same time, AI programs offer virtual testing tools for anticipating the attractiveness—hence the commercial success—of virtual worlds.

Section 9 covers the main points of biologically based beauty proposed as an essential background component of all healing environments. One major feature is the clear definition of the vertical axis needed to satisfy the body's gravitational reference. Even though verticality is often violated in the design of some buildings of the past few decades as a willful "transgressive" statement, doing so in virtual worlds is not recommended. Bringing in the concept of "cognitive capture" as one piece of an explanatory framework situates our suggestions in a broader mental model of how ideas are uncritically accepted by society.

Our conclusion, Section 10, summarizes ways in which designers of virtual worlds can determine whether they have a successful result in terms of what this article recommends.

3. Nature, Beauty, and Health

Extensive research shows that people find natural environments beautiful, and exposure to natural surroundings has been shown to exert a plethora of positive effects on mood [20], stress reduction [21], concentration and working memory [22–25], self-perceived health [26], self-esteem [27], recovery from surgery [6,28], as well as a reduction in criminal behavior [29,30]. Despite being an essential part of cultural folklore and inherited traditional wisdom, quantitative measurement and verification of the sensory effects of nature on health were only made possible by very recent technological developments. Neurological responses to environmental stimuli—in particular, visual ones—settle centuries-old questions of why natural settings are important for keeping the human body healthy.

These findings support the "biophilia hypothesis", which suggests that humans have an innate affinity for the natural environment and indicate that exposure to it can affect mental and physical health positively [28,31]. As humans evolved through being exposed to the geometry of nature, this mathematical/visual information field seems to have had a profound impact on the way that we connect to natural forms. "Structural" visual features of the environment can also be found in all pre-modern architecture, and those physical patterns are associated with the same positive health effects. An in-depth discussion about this "geometry of Nature" that permeates all natural and pre-modern artificial structures can be found in a number of publications and is beyond the scope of the present essay [32–36].

It is important for the present study that virtual environments mimicking natural ones reproduce the beneficial healing effects of physical environments [37–43]. Moreover, researchers are starting to use virtual environments to confirm and further investigate the impact that environmental geometry has on the users of architectural spaces [44–47]. These findings cannot be overemphasized, as they establish a link between healing and special informational properties—mainly visual—of the environment. That is, healing is triggered by special qualities that can be deliberately designed into both physical and virtual worlds. Design merges with medicine to inaugurate a vital new discipline.

4. Healing Beauty in Virtual Worlds

This section collects and lists distinct but related results from the gaming community. Virtual worlds have developed through an evolutionary process of trial-and-error, spurred by commercial considerations of market appeal. For the purposes of this paper, this discussion serves to underline the crucial separation of video games and the computer–user design interface (UX) from the standard design community coming from architecture and industrial products. Emotional/visceral appeal plays a crucial role in a successful process. This, in turn, is tied to objective beauty that arises from biological and mathematical criteria, not ephemeral fashion or intellectualization. While the data exist in the previous literature, our contribution is to synthesize them and draw strong conclusions from the synthesis.

4.1. Beauty in Video Game Worlds

In a study of what makes virtual worlds compelling and inviting to long-term play and interaction, Lee and Chen demonstrate that one key factor is aesthetic appraisal and that virtual worlds can be made more inviting by including beauty, variety, and breadth [48]. Importantly, visual beauty that features here corresponds to objective beauty that is related to a positive-valence visceral experience. This is entirely separate from intellectual appreciation or evaluation that could be totally subjective.

A good recent example is the video game *The Legend of Zelda: Tears of the Kingdom*, which was released in May 2023 to become the fastest-selling Nintendo game ever in the Americas [49] and see universal critical acclaim [50]. The game is noted for the immersion and beauty of the virtual world it portrays [51]. The Nintendo Switch platform shows the users how many hours were spent playing each game, and at this time of writing, fans are proudly sharing on social media how many hours they have spent playing *Zelda* [52].

4.2. Post-Avatar Depression Syndrome: Feeling down after Leaving the Theater

The *Avatar* film series directed by James Cameron is known for its stunning visual effects and, in particular, the lush, beautiful world that it portrays. When the first film was released in 2009, news outlets reported on "post-Avatar depression", or the extended feeling of gloom and dissatisfaction that persisted after they saw the film. The causes of this, in short, were the contrast between the pristine natural world depicted in the film in contrast with the soulless, developed physical world. Some viewers even reported suicidal ideation [53]. When the second film was released in 2022, such experiences surfaced again [54].

In analyzing what makes the world of Pandora (the habitable moon that is the setting for Avatar) so beautiful, commentators have pointed out that, to begin with, it depicts a natural rainforest environment replete with visual complexity and well-developed levels of scale (objects ranging from very tiny to mammoth), as well as ubiquitous curves and spiral forms. Beyond this, many of the plants are bioluminescent, creating multiple sources of soft light [55]. The fact that the plants do not just reflect light, as in a real-life scene, but actually project it makes them stand out even more and creates scenes with higher "doses" of natural geometry. This is a source of (*soft*) *fascination* which, together with *coherence*, provided by the organization described above, can make the scenes especially appealing [22].

4.3. The Metaphor of Architecture Applied to Digital Worlds

We *build* websites and software, not just make them. We say our websites and apps have software *architecture*, not structure in general. Such architectural terms are commonplace in software development and have been since the 1950s. As Halsted chronicles [56], such metaphors were initially adopted to emphasize a focus on the end-user of software; the needs and preferences of end-users were not much considered before then, but this metaphor eventually led to the field of human–computer interaction and the design paradigm of human-centered design. The metaphor of architecture also suggests a process of planning (that is, of design) in software development, occurring separately from and before the concrete work of building.

Here is where the application of Alexander's design patterns creates a significant overlap between building architecture and software architecture [57], suggesting possibilities for future synergy. The point to note is that Alexander's patterns [58] generate adaptive environments whose principal feature is a high degree of "objective beauty", leading to psycho-physiological well-being [59]. The pattern language framework was ported into the computer world with great success in many distinct venues, not only software [60]. But we find it rather odd that the present-day effort to design virtual worlds so far neglects design patterns, despite their potential central role in shaping all types of environments. Design patterns tend to be used simply as a communicative tool in software engineering and interface design [61] rather than for their deeper purpose (in Alexander's estimation) of creating a living structure.

Kalay and Marx argued early on that it is necessary to design virtual worlds not as abstract spaces but as connected ensembles of places. The distinction is that *spaces* are impersonal and indifferent, whereas the geometry and informational content of *places* allow users to connect viscerally to them. (This also resonates with Heidegger's ideas about dwelling, discussed in Section 5 below.) People will seek a visual environment with which they can engage and experience from different viewpoints simultaneously, one that is adaptable, memorable, etc. [62]. The most successful environments, physical or virtual, have deep-seated attractive characteristics. Human neurological responses explain why the body unconsciously pushes a person to move in a particular direction, stimulated by the surrounding information field [63]. By contrast, an uninviting environment generates stress when one is forced to inhabit or move in it.

As previously mentioned, the appropriate design patterns channel a design in the direction of adaptivity to users. Connective design patterns for physical environments, for example, *2.4 Biophilic Urbanism*, *6.1 Place Network*, *12.1 Handles*, *12.3 Friendly Surfaces*, *15.2 Human-Scale Detail*, *15.3 Construction Ornament*, and *15.4 Complex Materials* [59], also transfer to virtual worlds. The project of designing virtual worlds needs to figure out which tools from the physical world to emphasize and which to discard—virtual places are free of materiality and hence do not require tectonic elements ported from physical architecture [62]. Instead, the emphasis ought to shift almost entirely to connective place-making techniques, now supported by neurophysiological data.

4.4. Flatness and Mindless Repetition, Threatening to Overtake the Digital World

A basic question for designers of virtual worlds turns out to be, how complex should it be? As will become clear from our discussion, objective beauty requires a certain threshold and organization of visual complexity; hence, it cannot arise in a monotonous environment.

To begin with a broader observation, notice how over the past decade, the term "content" has grown into an umbrella term that covers everything that can be found online, from academic research and newspaper articles to videos and artwork and even pornography [64]—as if all of these are the same kind of thing. At present, humans are just "content creators" [65]. One manifestation of such "flatness" is to impose a lack of variety, as if that somehow helps to achieve economy of scale. That notion is absurd, yet it persists in a visual typology of minimalism that eschews any variety. This, of course, creates an environment of sensory deprivation that is shunned by users, which is not exactly a useful prototype to apply to virtual worlds.

Previous work on monotonous repetition in visual environments is enough to condemn this design typology, even though it became an accepted standard during the 20th century. Physiological measurements reveal that monotonous repetition disturbs the human cognitive process and can lead to anxiety and headaches [66–69]. These results uncover a disturbing contradiction between the images of simplistic modularity linked to crude industrial production and actual human reactions to built structures that embody those images. Despite the documented evidence, it has proved impossible to convince the architectural profession to drop this noxious building typology from practice. The early

20th-century myth linking the *appearance* of efficiency (unrelated to the real efficiency of any process) by means of monotonous repetition is stuck in the collective consciousness [70].

This historical background explains why the look of most buildings in virtual worlds follows these typologies. They have become the default building designs, and VR creators transfer them into virtual worlds without considering what purpose those typologies would serve there. The deliberate construction of unfriendly environments is a special case, of course, but what is remarkable is that VR designers often create such environments unwittingly by following the current norm in the physical world.

4.5. On Beauty Being Absent from Considerations of Digital Design

An everyday understanding of "good design" (mostly among non-architects and designers) almost certainly includes some reference to beauty. In the technology field, however, the common understanding of "good design" has long been completely separate from beauty. For example, in Gould and Lewis' seminal article defining the tenets of user-centered design, no mention is made of beauty [71]. For them, rather, good design is about a focus on users, empirical measurement, and iterative improvement. Noted design theorist Donald Norman (who coined the term "user experience" in 1993) even suggested in his classic *The Design of Everyday Things* that "beauty" is used to cover up design flaws related to usability [72].

To be sure, other digital designers have examined the role of beauty in digital design, discovering links between beauty and usability. The academic results have been nuanced and mixed in certain respects, yet there has been a discernible "aesthetic–usability effect" which states that users perceive aesthetically pleasing designs as more usable [73]. Alexander argues that, in good design, beauty and functionality both spring from the same source. It is not a question of either/or. In the best designs, the different elements help and strengthen each other, and in so doing, the whole also becomes more beautiful.

Why are digital designers not anchored on and driven by beauty? Perhaps because our schools do not teach how to create beauty anymore [74,75]. As the dominant culture does not produce environments with visceral beauty that trigger a nourishing physiological state, the methods for producing it remain a mystery to most people. Where is a young designer who has a gut feeling for beauty going to learn its basic principles to apply to their work? (So far, Alexander's books are not standard texts in Art and Architecture courses.) But the problem goes far deeper: the collective narrative falsely proclaims that a logical basis for beauty does not exist; that the notion is totally subjective. Defining objective beauty becomes a terrifying prospect for certain people.

Another reason for this neglect may be that digital design has its roots predominantly in computer science, and while this field may lend itself to beauty in the sense of elegant mathematical solutions and beautiful programming languages, it has not historically explored beauty in terms of the experiences end-users have with the software. As the field of user experience has grown over the past two decades and taken hold as a profession unto itself, education and research on digital design are beginning to acknowledge beauty, but this is still nascent. For example, the major textbook in the field, *Interaction Design*, by Sharp, Rogers, and Preece [76], whose sixth edition has just been published at the time of this writing, makes virtually no mention of beauty or aesthetics. The exception is a single paragraph (p. 182) mentioning the aesthetic–usability effect discussed above.

A deeper reason may lie in the historical, philosophical trend toward "objective" knowledge, which at some point began to exclude experiences like beauty as "subjective". This trend has its roots in 17th-century philosophers like René Descartes, for whom subjective knowledge was seen as "unscientific" and, therefore, to be ignored. Indeed, around the time of Descartes, Sir Henry Wotton famously translated the "Vitruvian triad" of firmitas, utilitas, venustas, as "firmness, commodity, delight"—even though the literal meaning of the Latin word "venustas" is indeed "beauty". This was a revealing edit.

More recently, subjective experiences have famously re-entered the scientific purview through fields like neuroscience, psychology, and evolutionary biology. Even mathematicians have been able to describe the various properties that are consistently perceived as beautiful, including

specific classes of symmetric and fractal structures [33–36,77]. Alexander reveals that objective beauty is anchored on scientific truth, a conclusion reinforced by the experiments referenced here [18,35]. To help ensure that a virtual world is restorative, designers are recommended to search for the inherent/latent/unrealized beauty unsullied by the pursuit of fashion.

4.6. Beauty Defined for Physical Architecture, Then Ported into Virtual Architecture

A unifying theme of this essay is transferring visual environments from physical to virtual reality. Inexplicably, this has not generally been approached as a classic problem in porting a user interface across platforms (for which techniques are known). Despite the commercial importance of doing it right, developers naïvely assume that dominant architectural styles are fit for virtual worlds without extensive modifications. The process is compromised, however, by (1) porting tectonic elements from physical architecture that are irrelevant and unnecessary in a virtual context and (2) porting design elements that discourage users in either platform.

We previously undertook a research project to document the essential geometrical ideas underpinning objective beauty [34,66,70,77–80]. This project follows the notion of beauty as a necessary organic constituent of the human environment, introduced by Christopher Alexander [18,35,81–83] and, in parallel, by the philosopher Sir Roger Scruton and others [84]. The current traditional architects always focus on objective beauty [85,86]. We argue that the widely perceived failure of objective beauty in virtual worlds was due to ignorance of the methods for producing it and propose developing a pattern language for designing the metaverse [87]. Professionals working to create an attractive virtual world simply copied the dominant aesthetic from physical buildings without realizing that it does not lead to visceral beauty but often its opposite [88]. As further support for this conclusion, consider how the physical architecture of the clustered tech company headquarters that are involved in virtual world innovation in the US is surprisingly unattractive [89]. Even though design rules for producing a wonderfully health-enhancing environment are known, they were ignored in favor of banal modernist or 'fashionable' building designs.

We have also previously discussed the success of the Roku City screensaver [87]. The presence of rows of coherent and detailed human-scale façades in this environment, ranging from Art-Deco to Neoclassical, represents an area that users want to inhabit, despite the presence of some unnatural features, like the purple-blue light that bathes the scene. This demonstrates that it is not the exact replication of an existing, real-world scene but the incorporation of specific types of geometrical organization that makes this VR environment attractive. In addition, the extensive natural park and open water that separates this area from a dense built-up city seen in the far distance, where monsters, pirates, and even an erupting volcano can be found, create an archetypal prospect-and-refuge scenario, where the coherent environment represents a refuge, from where potential threats, situated in an industrial-modernist environment, can be monitored from a safe distance [90,91].

Here, we see that multiple levels of perception and reaction patterns, deeply rooted in our very distant past, are played out in a digital environment not explicitly created to utilize them. Instead, this resonance is brought about by a visual vocabulary shared viscerally by the designer and the users.

4.7. Apple Vision Pro Design Guidelines

In June 2023, Apple announced its upcoming line of mixed-reality headsets, the first product of which, the Vision Pro, will be released sometime in 2024. As a mixed-reality product, the device allows users to undergo fully immersive experiences in virtual worlds (virtual reality) as well as experiences in which digital elements are overlaid on the user's real physical environment (augmented reality).

As with all their platforms, Apple has released a set of guidelines for designing its Vision products [92]. Throughout these guidelines, an emphasis is placed on creating a beautiful and comfortable experience for users. Some of the specific guidelines include leveraging space and naturalistic gestures so that users "feel at home on the device", using a

"glass" background whose translucent appearance adapts to its physical surroundings [93], and designing objects (including icons) with multiple layers to include complexity, shading, and depth, like objects in the real world [94].

4.8. Virtual Therapeutic Environments

Virtual worlds can be designed to offer a therapeutic environment by applying the appropriate qualities [95,96]. Changing the actual physical environment to enhance informational health benefits is strictly limited, with practical options being restricted to altering the color illumination or the piped music. It is not feasible to change room dimensions, physical spaces, surfaces, the placement of doors and windows, etc. A virtual world, however, has unlimited freedom to introduce changes in real time and to assess their effects on users through sensors. State-of-the-art wearable sensors recognize physiological changes due to positive emotions, thus documenting the user's state of well-being [97,98]. This possibility of easy experiments performed by adjusting a virtual environment to regulate users' emotions towards a positive mood offers enormous opportunities for improving human health.

Creating adaptive virtual environments that respond dynamically to the users' perceptions in real time opens the door to a new era of research [99]. A mechanism based on neuroscience data can exploit such a feedback loop for investigating the geometry of healing environments. A physical and virtual design can use design characteristics associated with a positive state while new results continue to augment the applied knowledge base. This research will add to and complement documented design patterns that are discovered by analytical observation, and new results could be formulated in terms of new patterns.

A study that manipulated architectural variables in virtual reality shows how this could be performed. The shape, size, color, and curved walls of a virtual space were changed while observers recorded their responses to the changes [100]. The authors of that study concluded that human aesthetic experience could be reduced to the three factors of familiarity, excitement, and fascination, partially overlapping with findings using images of interiors where fascination, coherence, and hominess were identified [101]. A different study varied the characteristics of indoor virtual environments (e.g., ceiling height, wall color, floor material) and recorded the users' responses [102].

The COVID-19 pandemic gave an incentive for research into the healing effects of visual input. Several independent investigators reached the same conclusions on the characteristics of a virtual healing environment—fractal shapes, color, plants, natural scenery, etc. [103]. The design of simulated places is based on existing computer games that utilize these factors to create attractive settings. Yet another application of VR simulations reduces chronic pain in a broad spectrum of cases [104]. Again, this simulation is based on creating an engaging, pleasant, and rich visual experience. A very different VR application employs realistic scenery to help combat veterans suffering from PTSD (post-traumatic stress disorder) go through healing exercises [105]. Therefore, diversified VR healing applications can all be attributed to the specific geometry of "living structure".

4.9. Virtual Worlds Competing with Tourist Attractions

International tourism provides a time-tested precedent for environments that attract users. People happily spend money to travel to a location, then spend more money on activities there if that spot is viscerally attractive. Tourist destinations include locations of natural beauty and built beauty embedded in traditional architecture and urbanism. Those informational environments lure people out of their own everyday settings with the promise of experiencing vastly augmented beauty. The aesthetic aspect, rather than the historical context that is always touted, is what attracts users [106,107]. Recent studies rank the restorative sensory effect from historical architecture to be comparable to that obtained from natural scenery [108].

Creators of virtual worlds can learn valuable lessons from the tourism industry. Sensorial qualities common to natural and traditional architectural environments are the opposite of industrial-modernist, minimalist, or Deconstructivist structures [18,35,36,63,70,77–83,86].

Without wandering off-topic, we mention that Disney World created a highly successful model of a new simulacrum or emulation—in a sense, a good example of a "physical virtual" world [109]. A lot has been written about Disney undertaking original research on the elements contributing to viscerally attractive environments while ignoring the advice of mainstream architects [110].

4.10. Contradictions with Design Education

Starting from the Bauhaus's central ideological aim, architectural education erased historical building precedents in a radical wave of innovation. Identifiable historical content in new buildings was explicitly condemned starting from the beginning of the 20th century up until post-modernism, after which historical references were allowed only as sarcastic jokes, not as integral components—with the exception perhaps of British postmodernism [111]. Dominant architectural culture ignores the few architects practicing a traditional idiom as not being part of the mainstream [86,112–116]. Since mainstream opinion forbids using traditional techniques to build at present, students are not taught how to create places with the same visceral attraction as historical ones and are, moreover, morally forbidden to do so. This rigid restriction leaves little room for the injection of objective beauty into virtual worlds, which can consequently be achieved only by sidestepping dominant architectural culture.

Readers of this essay, such as developers and users of gaming and virtual worlds, might imagine that our warning against engaging architects is exaggerated. Nevertheless, the disciplines split because of inherently distinct methods of design validation. An essential prerequisite for adaptive design is to collect and synthesize factors that affect users' unconscious behavior in real and virtual environments, which is what is attempted here. But note that our references come from the scientific literature—all of them outside architectural academia. The documented research contrasts starkly with current architectural thinking [87]. This striking disparity underlines the little-known fact that architecture students are not trained to do research, do not know the fundamentals of critical investigation and scientific reasoning, and misuse the term "research" to describe the results of artistic variation [36,70,117]. Despite lacking the indispensable skillsets of adaptive design validation [118], architects present themselves as being uniquely qualified to design virtual worlds [119].

VR developers should watch out for architects' misuse of scientific words to sell their designs [120–122]. Architectural texts can demonstrate great facility in appropriating and manipulating terminology from neuroscience, but ultimately their purpose is to promote either their author or some contemporary practitioner [123]. This is neither science, as it is not based on actual data, nor academic scholarship, but calculated marketing. Such discourse is confusing because it is dense with jargon—it almost makes sense but ultimately lacks logical consistency, like a bad AI program that produces plausible but nonsensical text [124]. The product (a photo of a building or rendering of a proposal) gives the game away by contradicting neuro-design principles, despite claiming the opposite.

5. Beauty in the Metaverse

An attractive virtual world has to provide an escape from the physical one. If not, then why enter it? Certainly, the activities offered to the user in the virtual environment are a major—perhaps the major—motivating factor, but the attractiveness of the virtual environment must also come into play. Given the deteriorating aesthetics on the ground in many parts of the globe, a virtual world will likely appeal to individuals whose physical environment looks severely industrial/modernist (this conjecture poses an interesting experiment that can be performed with existing online tools). Life in such surroundings is not very appealing, as perceived unconsciously by the human body, regardless of whatever aesthetics happen to be fashionable (and are imposed top-down by a heavy-handed construction industry).

In East Asia, millions of users of virtual worlds are drawn from among a population residing and working in dystopian, inhumane mass housing [125]. Indeed, the popularity of video games prompted the Chinese government to implement limits on kids' game time [126]. Dated "futuristic" architecture (from the 1920s, reinforced by Disney's 1955

Tomorrowland) is precisely the sort of unresponsive environment users are trying to sneak away from. Implementing "virtual reality greenspaces" provides a valuable measure to help people cope with stress due to chronic mental fatigue experienced in over-urbanized cities. By promoting attention restoration, VR exposure as a surrogate to nature may turn into a beneficial tool for improving health [127].

At the same time, the prospect of escaping physical reality—along with the responsibilities for negotiating the real world—for a virtual alternative can grow into a serious problem. We accuse architects and planners of having made the physical built environment so dystopic and flawed that being able to escape from it seems like an attractive idea [87]. Our long-term hope, however, is for this escape to trigger a massive reconsideration of how to create an objectively beautiful physical environment. The impetus will hopefully come from profit-oriented forces trying to draw virtual users back into reality, which will then help the world to implement objective beauty.

Many of our proposals resonate with VR developers who have heuristically discovered that users are attracted to virtual worlds. Chloe Sun lists a variety of generative art software that can be combined to create a more "living" virtual environment inspired by Alexander's foundational work [128,129]. Outside the insular world of architecture and art establishments, game designers are free to investigate evidence-based and intuition-driven design solutions [130,131]. Bringing these ideas together into an epistemological framework for VR helps define a design paradigm that is consistent with human neurological response.

The important point is that design patterns (both Alexandrian and software) did not originally focus on aesthetics, beauty, geometry, etc. but focused instead on "function" (i.e., forces, processes, etc.). The deeper sense of beauty was the topic of the more philosophical book *The Timeless Way of Building*, in which Alexander introduces the QWAN—the "quality without a name" [132–134]. To this day, Alexander's *A Pattern Language* is well-known and cited among computer scientists (though usually only in passing, referring to the "function" aspect of design patterns), while *The Timeless Way of Building* is much less cited. Still, computer scientists who recognize and value elegant software—beautiful programs—do reference the QWAN [135]. It is worth noting that Alexander's own understanding of the patterns greatly expanded later, during his writing of *The Nature of Order*, to embrace geometrical transformations and the emergence of beauty through iteration and growth, what he called "unfolding" [18,35]. This suggests certain resonances with software development, which is made iteratively and increasingly through the processes of human-centered design and with attention to broader aspects of human experience (dubbed user experience or UX) and not just narrow usability. It seems that the software people have been playing catch-up, but the ones programming the metaverse seem to have been completely left behind!

Is it possible for the metaverse to be a healing environment? Even before getting into Christopher Alexander's work, we can refer to Martin Heidegger's ideas of dwelling in space [136]. As Heidegger argued, "dwelling" is about being at home in one's totality—physically, psychologically, physiologically, and spiritually. At his time of writing in the mid-1940s, the dominant architectural understanding of "dwelling" was simply having a place to store one's physical body. But with his more holistic understanding of dwelling, Heidegger argued that for humans to feel truly at home in a place, it must have certain characteristics: a supporting ground, which he called Earth; a sense of something beyond (Sky); reminders for us of our own mortality, which helps us make the most of life (Mortals); and meaningful objects and experiences that we can undergo (Divinities). Environments, whether physical or virtual, that do not integrate these four elements, Heidegger suggests, will not inspire users to care for the environment or strive for meaningful goals, let alone feel comfortable or satisfied [137].

On the topic of how philosophers view habitable space, Gaston Bachelard described a desirable state of psychological well-being as follows: "I should say: the house shelters daydreaming, the house protects the dreamer, the house allows one to dream in peace." [138]. We interpret this condition as a state of the body free from anxiety induced by environmental stress and especially lacking cognitive stress due to hostile elements of the geometry. This is the

type of calming and effortless architectural experience that is conducive to human health and which invites us to explore a virtual world as if in a dream (but not a nightmare!).

Philosophical investigations on the sense of effortless belonging to places contextualize the question excellently and set a strong foundation for future health-centric empirical assessments of design features.

6. Opportunities for Further Research

While the metaverse took off with little understanding of underlying factors, that hype has subsided. Now that Apple has announced its upcoming headset for 2024, there is a renewed interest in designing for virtual worlds. It is fascinating to read their design guidelines (see Section 4.7 above). Following our analysis of the situation, it seems to the present authors that Apple is at the forefront of communicating what it could mean to design for a human being in VR.

The existing literature covers known impacts of online experience on health and well-being, which is mostly focused on social relationships. To complement this, we wish to investigate the primary effects of the environment itself on human well-being due to its colors, geometry, shapes, spaces, surfaces, etc. Even if we focus strictly on the presence and different types of complexity that incorporates symmetry, there are key results that affect health. Our work on symmetry helps to document its relationship to salutogenic structures and their opposites [77,139–141].

We understand the extensive challenges involved in conducting rigorous research in this area. Yet we urgently need to see a method of analysis developed further that resolves existing conundrums. One of these is a contradiction in terms where contemporary architects love their designs and characterize them as "beautiful", whereas they are not attractive to others. Future research should help to distinguish idiosyncratic from objective perceptions of beauty.

A fascinating perspective has been added by the finding, with functional MRI, that the processing of recursive (fractal) forms recruits different resources from the processing of non-recursive forms. Remarkably, this process recruits the Default Mode Network, a functional brain network known to be involved in the processing of internal information across multiple forms of complex cognition, many of which are linked to memory or abstract thought [142,143]. This implies that such forms (clearly showing multiple nested symmetries interlinked by scaling symmetries) are higher in perceptual fluency, and do not require specific task-oriented networks for their processing, something that fits well with the concept of "soft fascination", i.e., the involuntary effortless attention induced by natural stimuli, as opposed to "directed attention", i.e., the voluntary use of attention for task execution.

Some interesting initial papers relate to the physiological effects of visual stimuli in non-virtual worlds [144,145]. The question is: how to use those results obtained from the physical world to better design virtual worlds? But then this definition raises more questions than it answers. However, they are the RIGHT questions by asking WHO is doing the designing, in what context, and HOW do we know what the right (effective) courses of action are? How do we really know what th

e existing conditions are (since these are complex and all knowledge of them is incomplete)? And especially, how do we know what conditions users really prefer? What happens when those change?

Many young people (and increasingly others) spend countless hours in virtual game environments already. A recent survey showed that teens spend an average of two hours a day playing video games! So, one need not buy all the boosterish speculation about the virtual future to have reason to be very concerned about the existing (and growing) impact on mental and physical health.

This paper shifts the emphasis a little bit. The idea is that there is an unmet professional responsibility to make actual healing environments, whether they be physical or virtual. So far, the architect's innovation has been given unchecked free rein, sometimes at the expense of human health. We are not giving the design professionals "a pass" so to speak. Instead, we focus on the fact that so many billions of people spend increasing amounts of time

online and that in itself poses a grave health threat [146]. Therefore, there is a professional responsibility to make virtual worlds into healing environments, to the degree that this is feasible, by employing the best of our relevant scientific knowledge and skills.

The next step is the more important one: we can apply those lessons learned from virtual worlds to shape the physical world and upgrade its ugly spots. This is an example of "connecting the dots" to existing research. We must deal with the impacts of aesthetics on health and well-being, with a focus on brain function (e.g., the important work of Semir Zeki and closely related research) [147–149]. Cleo Valentine's work on neuroinflammation defines new and important directions in this investigation [150].

7. Neurological Appreciation of Beauty: Insights from the Five-Factor Model in Psychology

A deeper understanding of who uses virtual worlds and why relies on discovering what motivates the users. Clearly, a need to search for emotional experiences not provided by the physical world combines with the spirit of exploration to drive users. This drive is contingent upon particular character traits that vary among individuals.

To identify the personality profile that is associated more closely with this drive, we must look at personality traits. The most influential and widely used personality model in Psychology is the five-factor model (FFM). The FFM creates a personality profile based on the individual's position along five basic dimensions or traits, which have been identified by factor analysis: (a) Extraversion, (b) Agreeableness, (c) Conscientiousness, (d) Neuroticism, and (e) Openness to Experience [151]. Each of these major traits can be further analyzed into facets to give a higher-resolution analysis of someone's personality when that is required.

Costa and McCrae identified a more specific quality, *Openness to aesthetics*, or the trait *Appreciation of Beauty (tAoB)*, as a specific subtrait within the broader trait of Openness to Experience and described it as "a deep appreciation for art and beauty" [152,153]. *TAoB* was found to have the highest correlation to the trait of Openness than any other subtrait, indicating its significance and, potentially, its prototypical role in the overall trait of Openness.

Appreciation of beauty has also been positively correlated with traits (b) Agreeableness and (a) Extraversion [154]. By using factor analysis, Diessner et al. determined that there are, in turn, at least three sub-traits of *tAoB* (called Engagement with Beauty by these authors): (1) the trait of appreciating natural beauty, (2) the trait of appreciating artistic beauty (including Architecture), and (3) the trait of appreciating moral beauty [155].

A new study about users of the ZEPETO South Korean mobile chat app, where users create and interact as 3D avatars in different worlds, has revealed some interesting results about their psychological profile [156]. Zepeto users are higher on Extraversion and Openness than non-users; overall, they are driven by the desire to explore the virtual world and enjoy unique experiences, but such a tendency was stronger among those higher in the traits of Openness and Agreeableness, while those high in the trait Neuroticism were seeking more of an escape from reality.

In another recent study, a meta-analysis examining general social media use, Extroversion and Openness were significantly and consistently related to the use of such platforms [157]. Internet addiction, on the other hand, correlates with different personality profiles; Neuroticism has been shown to be positively correlated with internet addiction, whereas Openness, Agreeableness, and Conscientiousness are negatively correlated [158].

When taken together, these results illustrate an interesting finding: (non-addicted) users of the metaverse, and social media in general, seem to score higher in exactly those traits that make them more likely to appreciate/engage with beauty. This correlation points us in the direction of a potential opportunity: these users, when exposed to beauty in a virtual world, are more likely to benefit from the aesthetically rewarding stimulus and, presumably, will seek to translate this benefit into the real world.

8. AI Can Discover Important New Results in Adaptive Design

Artificial intelligence (AI) is often discussed in the same context as virtual worlds. The development of AI opens exciting possibilities by providing tools with which to explore adaptive (which encompasses human-centered) design [159]. Multiple factors defined by neurobiology and physiology determine whether an environment can be used comfortably—or be avoided. The same human-centered considerations apply to virtual worlds, albeit in a somewhat restricted spectrum. The ensemble of human senses that play such a determining role in perceiving physical environments is reduced to the visual (and auditory) realms in virtual worlds. Because of the overwhelming preponderance of visual information in sensory stimulation that adapts humans to their environment, this restriction is not a major issue. We are not directly measuring what is known as "hedonic quality", referring to a positive subjective experience. Rather, we are referring to a state of positive health and well-being, which is an *objective* physio-psychological state that correlates with comfort and reduced stress.

So far, applications of AI to building design focus on generating abstract images unrelated to human adaptation; that is, creating a design that is visually attractive as a distant image, model, or object but whose suitability for human habitation and use is left unexplored [160]. We would like to draw attention to the totally distinct approaches to design practiced by adaptive versus conventional architects. Designing according to human sensibilities grounded upon biomedical data begins with the body's responses to colors, details, shapes, surfaces, symmetries, and volumes. The forms of environmental structures, whether representing a physical or virtual environment, arise from those adaptations. This process implies that nothing is arbitrarily imposed top-down. By contrast, the obvious human-centered considerations play little or no role in contemporary design as practiced by the dominant architectural culture. What we see instead is AI being used to generate random forms that look "innovative" and are destined to be built with standard global industrial-modernist materials. The design of virtual worlds follows this model whenever architects get involved.

However, any approach that tends to focus excessively on innovation for the sake of innovation, overlooking deep/systemic issues, etc., should be avoided. Lately, people have been using the alternative term "humanity-centered design" to try to capture more of an Alexandrian approach to this topic. The established profession is not interested in applying AI to explore design adaptivity to users. The 20th-century dominant architectural culture was never concerned with sensory feedback. Starting with early modernism, architectural culture has adhered to a top-down model that creates an image of a building, then introduces it into the world as a built "object". The decision-making process of generating physical forms in the environment as untested abstractions has been hugely successful for businesses and the building industry. Just like in the physical world, the same result in virtual worlds is insensitive to the physio-psychological factors governing human use, without, in this case, having the financial advantage that it has in the physical world.

AI tools make it possible to investigate the precise qualities that define an adaptive environment that enhances human health. Both verbal (ChatGPT) [161,162] and visual (Craiyon, DALL·E 2, DreamStudio, Midjourney, Stable Diffusion) [163] applications of AI can, and should, be used to explore what factors make an environment attractive and comfortable to experience. This program towards validation goes beyond any flashy attraction by privileging medically validated positive factors for well-being. The massive data bank that AI draws upon to either create imaginary images or to compose a verbal description includes billions of pieces of human data. AI applied to conduct research is akin to an enormously scaled-up survey of people's unconscious preferences.

The numbers win out—and we have already discussed how such applications always produce "traditional"-looking buildings (in the historical timeline up to and including Art Deco) when prompted to create a beautiful building image; versus industrial-modernist building images when prompted for ugliness. These results are consistent among themselves, as they also conform with biophilia.

Visual AI generators identify as ugly those environments that dominant architectural culture privileges as paradigmatic and which it impulsively transfers into virtual worlds. A disturbing question posed in this essay's Introduction—whether AI would generate dystopian virtual worlds—depends upon whether developers choose to enlist AI to design and validate healing environments (which look surprisingly different from the images that dominate architectural training). Visual AI is a powerful and useful tool that can generate either healing or uncomfortable designs. Society cannot relinquish this determining choice to those with a stylistic agenda. Moreover, the possible future development of AI suggests possibilities for creating nourishing virtual worlds beyond the human imagination; rather than appearing to us as "naturalistic", such virtual worlds might strike us as "otherworldly" but nonetheless comforting and homelike.

Adaptive architecture focuses on human needs from the immediate point of view of the user. It confronts and must solve a myriad of technical problems such as the optimal use of local materials; energy-savings through climate adaptation; integration of the building with nature; how to fit a building into the existing urban fabric; adjustment of spaces for human movement and psychological well-being; positioning of entrances and windows; designing unconsciously welcoming surfaces, etc. Many of these design constraints—particularly those that affect human senses—are shared with virtual worlds. This approach makes it easy to anticipate the valence (negative or positive) of the resulting user interaction.

Applications of both verbal and visual AI overwhelmingly verify what we already know from biophilia, design coherence, emotional affordances, fractals, symmetries, visual attention scans, etc. [79–83,87] The software, in its various applications, simply validates the informational content that is embedded in traditional and vernacular architecture. Beauty in nature arises when form merges with function, which transfers into the exceptional qualities of traditional architecture to generate well-being. The human-centered design avoids the established "canonical" building typologies that dominate current official construction since those represent a rather narrow establishment opinion: that validates designs exclusively by how faithfully they conform to a peculiar aesthetic [36,70,120,164].

9. Discussion: Escaping Cognitive Capture

This study argued for the importance of aesthetic experience in designing virtual worlds. It was important to define a particular type of aesthetic—biologically based objective beauty—to which the human body responds positively, though unconsciously. Bringing together previous results by many researchers, including the present authors, creates a synthesis of ideas about what people respond to viscerally. The design profession finds itself at a turning point when knowledge from mathematics, medicine, neuroscience, and psychology is rich enough to have predictive value. Yet this approach to design is still non-standard, being largely unknown to mainstream architects of either physical or virtual worlds.

The reasons for this state of affairs are beyond the scope of this paper, yet we can observe several important factors. What is known as "cognitive capture" [165], in which a population begins to take on the modes of thought of an industry or profession, results in a diminished capacity for independent or critical thought. Such a capacity is diminished because the population is distracted, or "blinded", by attention-absorbing features or practices, and their normal processes of discernment and judgment are allowed to atrophy. A related phenomenon is known as "architectural myopia" [166], wherein architects have been observed to make aesthetic judgments that depart from the judgments of most non-architects, in part because they are trained to favor aesthetics that conform to simplistic industrial geometries (a habit of thought described by the present authors as "geometrical fundamentalism") [19,70,87].

A similar problem can be seen arising in the computer science industry. The more primitive geometries of earlier graphics systems have come to dominate later graphics and even become popular—another instance of "cognitive capture", this time of the users. The problem is compounded by the atrophy of users' capacities for fine aesthetic judgments as they become

passive consumers of ever more random, titillating, but ultimately non-nourishing aesthetic experiences. For children, this represents a profound threat not only to their health but to their capacity to seek salutogenic qualities later in life and to participate in a democracy (and, in some cases, as professionals) in building more salutogenic environments.

There is, however, an alternative to this slow erosion of aesthetic quality and user capacities. As we have outlined here, verified adaptive design rules can now be applied with confidence to create virtual worlds that are not only appealing in their sensory effect but are healing in the long term and also afford the ability to develop capacities for richer aesthetic discernments and explorations [87]. We, therefore, urge developers to shape virtual worlds in the same way as giving free rein for children to color and ornament their immediate environment (before their inborn creativity is quashed by a dreary forced aesthetic). Having to inhabit the result puts a brake on dangerous fancies. Ordinary users will naturally be attracted preferentially to those mostly visual characteristics without "knowing" why (because the attraction is unconscious). No matter. A truly revolutionary development occurs if we can improve the health of users through the design of the virtual worlds in which they are immersed.

The issue of the incomplete nature of the virtual experience can be seen as a potential obstacle and has already been discussed [4,150]. A serious limitation of VR is the lack of gravitational sensation (and generally accelerational sensation, except in specialized installations) and, hence, the lack of multisensory integration. There is no doubt that these differentiate the experience of VR from the real thing, and this is why it can be argued that, in studies where simple reactions to images are investigated, there are some cases where it is better to show photos on a computer screen than to use headsets; because with the screen, we see what we expect, for example, a 2D image on a surface, without the perceptual dissonance of the VR headset.

Note that an unambiguous definition of the gravitational axis in the design of a building (both its interiors and outside appearance) is one of the factors of the "Biophilic Healing Index" [10]. Lacking an explicit vertical reference, or a virtual vertical axis defined through bilateral symmetry, such as an arch, creates problems in balance. We are referring here to a static effect due to the perception of environmental geometry and not to motion-induced nausea. Without getting into a discussion of this effect in physical settings, the analogous lack of a clear vertical reference is one factor that results in cybersickness [167,168].

Because of these problems, it has been argued that VR studies may be insufficient to fully capture the consequences of extended exposure on human health. But this does not bear on our discussion here. New studies are needed to investigate the effects of changing just one parameter, i.e., the aspects of the geometries presented, one at a time. All other parameters—exposure time, properties of the headsets and the operating systems, etc.—should be identical. From an experimental point of view, this would be the way forward. From a conceptual point of view, none of these concerns goes against our argument about the positive effects of incorporating truly biophilic design in the metaverse, all things being equal, regardless of the potential negative effects of spending time in the metaverse.

10. Conclusions

With the ever-increasing use of VR platforms, we now have at our disposal a whole new realm—whole new worlds, we might say—in which principles of human-centered, health-promoting design can be applied. At the same time, we are confronted with growing evidence of the health impacts of our virtual-world designs, both positive and negative—carrying normative ethical implications, as we have explored.

Design in these worlds is not governed by financial constraints, unlike the physical world of buildings and landscapes, and there is no reason, other than neglect, habit, reckless profit-seeking, or ideologically driven imposition, that these environments should not be built in the best human-centered way possible. Indeed, if designers see themselves as true professionals, then they surely have an ethical duty of care to the well-being of those for

whom they design. In this paper, we have proposed a normative standard for designers to provide a universal visual experience arising from a persistent background of biologically based objective beauty and affording the capacity of exploration, restorative play, and development of life skills in aesthetic discernment.

As we have argued in previous publications, in contrast to almost all of human history, the most recent century of design can best be characterized as a project to apply distracting fig leaves to a crude and unsustainable phase of industrialization: doubling down on "geometrical fundamentalism", industrial cognitive capture, and financially manipulative "art stunts". At a low level, the resulting aesthetic experiences are harmless carnival fun. However, evidence is mounting that, when consumed as a steady diet—as they are increasingly by people of all ages, and especially the young—such experiences are having a profound pathogenic effect, with long-term negative implications for a free and democratic society.

To be sure, virtual worlds can be expected to include ugliness, surprise, stress, and other painful aspects of life. These experiences can also be therapeutic when they are presented in transitory modes or from a sufficient perspective. The question for designers is whether the background environments are barren, ugly, overly mechanical, or otherwise degrading of aesthetic experiences—or conversely, whether they are restorative, naturalistic, richly complex—in a word, beautiful. A parallel question is whether users are passive consumers to be manipulated, titillated, and exploited or whether they are actively engaged in exploring (and creating) aesthetic richness.

The core argument is that designers of virtual worlds should focus on creating worlds that are, for the most part, restorative, naturalistic, engaging, and richly complex. Our suggestions to help designers do this boil down to two complementary approaches. One of them involves the technical application of design techniques abstracted from biophilia, fractals, nested symmetries, Alexander's 15 geometrical properties, etc., which are discussed in depth in our other work, as well as by other authors. Even though these methods do not yet constitute a standard part of mainstream art and design, their details are already spelled out in the literature.

The second approach is to trust one's intuitive and visceral feeling of objective beauty and not be led astray by existing agendas coming from the design profession. This method is far more direct but paradoxically more difficult to apply because of unconscious social pressure and the atrophy of healthy aesthetic discernment skills as a result of cognitive capture. Yet as Christopher Alexander and others have argued, it is possible to re-train one's body to liberate the child-like positive reaction to objective beauty that is everyone's evolutionary heritage. This could be facilitated in practice by employing wearable sensors that measure bodily responses (such as activation level, mood, and stress level), which resolve cognitive dissonance triggered by prevalent media opinions. Our discussion gave some practical guidelines for sharpening the appreciation of beautiful environments by paying attention to neurophysiology.

The way in which designers know they have achieved a successful result in terms of user emotions is precisely by what the users "feel". Over the long term, it draws users back for reasons they cannot clearly explain—it offers a comfortable, easy, emotionally intuitive fit. This unconscious reaction (related to Alexander's QWAN—quality without a name, see Section 5 above) might not be easy to describe, and for that reason, researchers and designers may be hesitant to attempt to operationalize it. We can ensure that a virtual world is restorative to a significant extent by how far it satisfies the geometrical criteria that link to neurophysiology and which come from human evolution. Of course, there will always be additional factors that are beyond our control. A virtual world need not be naturalistic—yet its geometry must satisfy the requisite mathematical properties. There is a place for beautiful, otherworldly places that succeed because they satisfy those properties, as we find in successful gaming environments. A scene "feels" real but does not necessarily duplicate nature. Note also that an emotionally successful setting needs to exceed a complexity threshold; otherwise, the requisite mathematical properties cannot be satisfied. If one looks carefully at a beautiful plain artifact or setting, it may indeed look very sparse

at first glance; however, one will invariably discover unnoticed layers of complexity that support its overall coherence.

We are optimistic about the opportunities, including further research progress. As one example, the recent advances of AI mean that the collection and integration of data from user experience in the virtual worlds (both positive and negative, as much of the virtual environment can be deliberately unfriendly in games) can be used to further promote human-centered design in the physical world. We are now standing at a new crossroads in the history of environmental design, and this is an opportunity—and perhaps a duty—that we should not pass by.

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