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WHOLENESS, VISUAL COMPLEXITY AND MATERIALITY: A COMPARATIVE ANALYSIS USING FRACTAL DIMENSION ANALYSIS AND THE MIRROR-OF-THE-SELF TEST IN THE CASE OF MATERIAL IMITATIONS

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Abstract. Architecture recently became a subject matter for research in scientific fields such as environmental psychology or neurology thanks to developed tools for measuring neural responses of humans to their environment. The so-called biophilic design promotes creating an environment for psychological and physical wellbeing based on human affinity to natural forms. Researchers such as Nikos Salingaros and Bin Jiang had a significant impact on the research of organized complexity in architecture based on the theory of wholeness by Christopher Alexander. This comparative study attempts to clarify some aspects of the relationship between visual complexity and wholeness by questioning material authenticity. For a quantitative representation of relative visual complexity, a fractal dimension analysis and architectonic life are used. A survey employs the mirror-of-the-self test developed by Christopher Alexander to receive a universally shared judgment on a degree of wholeness (life) of wooden floor sample and its imitations in ceramics and vinyl. Results confirm the assumption that a higher degree of complexity is proportional to a higher degree of life when comparing images. However, when comparing material samples, the majority of respondents agree that more authentic and less processed materials have a higher degree of life than imitations with a higher degree of complexity.

Keywords: *visual complexity, material authenticity, mirror-of-the-self test, biophilic design, structural beauty, architectonic life, wholeness.*

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1. Introduction

Since Vitruvian times, architecture is considered both art and science, as it can embrace and synthesize *firmitas*, *utilitas*, and *venustas* – i.e., strength, utility, and attractiveness in the buildings. The three aspects remained valid criteria and motivations for the co-creation of our environment until today, but new interpretations were assigned in every age following the cultural context. In the contemporary – late modern – era, the domain of industry and technological progress are taking care of *firmitas* and *utilitas.* As it derives knowledge from science, the interpreter of truth as objective reality, the subject perceives the world of facts from a detached position. The resources such as space, time, or material are treated as life-less substances. Even life and meaning are comprehended as mere functions of systems. Thus narrow-minded industrial thinking leads to a mass production of buildings and cities that secures sole utility. On the other hand, modern art and architecture manifest apparent freedom from values that became relative, arbitrary, or even irrelevant. The attractiveness (*venustas*) of architecture does not commit to harmony or coherence, but rather on abstract concepts or sensation-seeking fashion. Both

aspects of modern architecture, utility orientation, and arbitrariness of architectural language had been criticized for the lack of human scale, coherence, or sense of place, which we know from traditional architecture and a natural environment. The lack of emotional or spiritual attachment to our newly built environment gradually became tangible when new evidence of, e.g., neurological research showed our bodily responses to the environment regardless of our taste or opinions. With the criticism, a new school of thought emerged striving for the humanization of architecture, by rediscovering the nature of order and the position of self in the world picture.

This paper starts with a brief introduction of the theory of living structures and wholeness by Christopher Alexander, who described a quality that is essential for our connection to nature and ourselves. It is followed by presentation of attempts for quantitative measurements or estimation of the desired quality. The issue of the organized complexity of architectural form and urban fabric is addressed in the works of Nikos Salingaros and Bin Jiang. The introduction part is followed by a formulation of the research question based on the knowledge gap emerging between visual complexity and wholeness.

Christopher Alexander, architect and mathematician rehabilitated a theory of architecture based on knowledge of the order of nature. In his book The Nature of Order (2002–2005), Alexander describes the principles of how beauty, harmony, and function form an undivided whole. The quality that Alexander finds in nature and traditional architecture and misses in the 20th-century architecture, he calls "wholeness", "life". The concept of wholeness reveals how geometrical organization in the physical world corresponds to the wholeness of being in our daily experience and from this relation Alexander reopens the question of beauty as being an objective structural phenomenon rather than a subjective and arbitrary construct.

Christopher Alexander describes *15 fundamental properties of living structures* (Table 1) which also serve as possible *structure-preserving transformations*. (Alexander, 2002–2005) The natural environment as a complex self-sustaining system creates forms of a high degree of wholeness and this quality is desired in any man-made structure as it provides coherence, function, diversity and above all – meaning. Alexander developed a comparative method for detecting a relative degree of wholeness between two subjects. The method called the mirror-of-the-self test is used for answering a research question proposed in Section 2.

Table 1. 15 fundamental properties of living structures (Alexander, 2002–2005)

levels of scale	good shape	roughness
strong centers	local symmetries	echoes
boundaries	deep interlock and ambiguity	the void
alternating repetition	contrast	simplicity and inner calm
positive space	gradients	not-separateness

Nikos Salingaros, a former physicist and mathematician, for the last few decades, conducts his research on the theory of architecture and gathers arguments and evidence from various fields of science to promote a more humane architecture. He claims that design and scientific research tends to converge in a way that an architectural practice could be based on knowledge of healing properties of natural forms rather than on a mere

function, fashion, or taste. (Salingaros & Mehaffy, 2015) From this proposition, the term scientific theory of architecture could be attributed to Nikos Salingaros. (Horacek, 2013) Salingaros' research of complexity in architecture includes the notion of structural order, fractal properties, and his model for estimating architectonic life (Salingaros, 2006).

Significant advancement brought up a combination of neuroscience, biology, and psychology, which can verify subjective, yet universally shared visceral responses to the built environment. (Pallasmaa *et al*., 2013) In his books A Theory of Architecture (2006) and Unified Architectural Theory (2013), Salingaros collected evidence about strong positive correlations between organized complexity of the environment and e.g. brain size (Kihslinger, 2006), reduction of stress (Wise & Taylor, 2002; Taylor 2006) or better cognitive performance. One of the latest studies by Salingaros and Ann Sussman shows how traditional building facades engage the observer unconsciously regardless of their style preferences. (Salingaros & Sussman, 2020).

Natural forms of organic and inorganic origins manifest great complexity, i.e., the diversity and coherence to which humans adapted and attuned during the millennia of evolution. Our intuitive affinity to life and living forms is formulated in the context of psychology and biology as the biophilia hypothesis (Kellert & Wilson, 1993) and it is argued as an inherent part of our neural apparatus. The notion of living structures by Christopher Alexander allows us to study all forms – including organisms, geological forms, or architecture – in the same manner of parts-whole relationships. Altogether, it leads to the notion of adaptive design, meaning adaptive to the natural environment and adaptive to the nature of human cognition.

The knowledge about ornament, its engaging and nourishing effect on our perception, is one of the most relevant issues for this paper. Ornament is intimately linked to human intelligence and increases the coherence and complexity of the environment that resonates with our innate way of processing information. (Salingaros, 2015, 2020) Through refining small-scale ornaments and levels of middle scale, architecture can resemble the fractality of the natural environment. (Kellert *et al*., 2008; Salingaros, 2015; Coburn *et al*., 2019, Joye, 2007) Many traditional ornaments directly mimic natural forms, but not in a realistic manner but rather as an abstraction or stylized form, showing even more symmetries than the model. (Salingaros, 2006, 2015).

Bin Jiang, a researcher in geo-informatics and urban sciences, proposes other ways to approach organic order through quantifiable data modeling. As Christopher Alexander describes wholeness as analogous to beauty and life in structure, so does Bin Jiang conclude that a computational model of wholeness can provide a mathematical model of beauty or life. Jiang essentially derived two principles – Scaling law and Tobler's law – that a living structure obeys. Scaling law says that there are far more small things than large ones and reflects one of the 15 properties of living structure – *levels of scale*. Tobler's law (or the first law of geography) says that everything is related to everything else, but near things are more related than distant things. Jiang states that this law reflects the remaining 14 of the properties, probably except for the property of *not separateness*. (Jiang, 2019).

In the case study of measuring the wholeness of the Alhambra floor plan, Jiang uses the PageRank algorithm to determine the relatedness of each center to its surrounding ones. "…beautiful centers are defined as those to which many beautiful centers point. This definition of beautiful centers is recursive, and computation of the degree of beauty is achieved through an iterative process until convergence is reached." (Jiang, 2015).

For measuring the scaling hierarchy of centers, Jiang uses the head/tail breaks algorithm, where the number of recursions called ht-index attributes to the degree of structural beauty. (Jiang and Yin 2014) Jiang formally defines structural beauty according to a formula $L = S \times H$, where L is life, S is the sum of parts (centers), and H is the number of levels of scales (ht-index). Based on his measurements, Bin Jiang claims, e.g., that the Blue Poles painting by Jackson Pollock is structurally more beautiful than Mona Lisa by Leonardo da Vinci. (Jiang & de Rijke, 2021).

2. Research questions and comparative cases

Both Nikos Salingaros and Bin Jiang made progress in elaboration, some of the concepts deriving from Christopher Alexander's notion of wholeness. They study architecture and urban fabric as a complex system using visual representations in mathematical models and they proved strong correlations between organized complexity and life in structures. However, both adhere to the Cartesian method, which can deal only with objects isolated from their context and the observer's cognition. They both take the assumption of beauty as an objective and real phenomenon in the mechanistic sense of objectivity – as quantity. Therefore, they select from the 15 properties only those easily quantifiable, mainly *levels of scale*.

In their studies, they use the terms beauty, wholeness, and life in structures referring to Christopher Alexander. However, Alexander in his work The Nature of Order (2002–2005) almost recursively describes the notion of life in structures on two thousand pages to avoid misleading reductionism. In the chapter Beyond Descartes and the whole fourth volume, The Luminous Ground, he even calls upon crossing over the positivistic standpoint, which could allow us to comprehend the paradoxical nature of the creative order. Beauty in Alexander's viewpoint may be considered as an objective actuality, universally shared value, a real quality of the physical as well as the inner world of the observer. However, it is not meant to be a measurable quantity in the mechanistic sense. Alexander's note to a writer Mae-Wan Ho fits into the context of this argument:

"They deal with the whole and they describe wondrous behavior in the movement of the whole. (…) But what she describes are still mechanisms. No matter how dedicated she is to a new vision, how hard she tries to bring in the new understanding of wholeness in physics, the language of mechanistic science keeps getting in the way. The wholeness itself does not yet appear in the actual calculations as a structure. (…) The personal, the existence of felt 'self' in the universe, the presence of consciousness, and the vital relation between self and matter- none of these have entered the picture yet, in a practical or scientifically workable way. In that sense, the world picture, even as modified, still deals only with the inert- albeit as a whole." (Alexander, 2002, pp. 17).

If I take, e.g. Jiang's provocative conclusion about Jackson Pollock's Blue Poles to be structurally more beautiful than Leonardo da Vinci's Mona Lisa (Jiang, 2021), I would oppose that this counterintuitive conclusion is a result of pure mechanistic calculus which is on the very opposite side of the idea of wholeness proposed by Christopher Alexander. To give just brief reasoning, a human face is so delicately adapted and it is one of the first things in life we attach to. As Ann Sussman puts it, our survival depends on our connection to it. (Salingaros & Sussman, 2021) "…the human brain devotes more area to face recognition than the recognition of any other visual object…" (Kandel, 2012). It is very unlikely, that the woman's face with so carefully rendered ambiguity in her

expression, that it almost “comes alive”, would anyone find less beautiful or felt less self than in fractal patterns of the Blue Poles.

Christopher Alexander himself considers the mirror-of-the-self test and its variations based on deep feeling as a primary instrument for "detecting" life in structures, whereas an analysis of the properties as secondary. He shows examples of unequivocally more complex structures that do not pass the mirror-of-the-self test. For example, a simple Danish cottage shows more self than a highlight of the baroque sacral architecture Les Invalides (Alexander, 2002, pp. 339).

Feeling as a primary tool for collecting data is used in a research method called feeling maps by Yodan Rofè (Weinreb & Rofè, 2013; Rofè & Pontikis, 2016), which he uses for the evaluation of the fitness of the urban environment for human wellbeing. Rofè also validated Alexander’s claim about the possibility of large-scale agreement about feelings in population. Another researcher, Kristina Börjesson who linked timelessness and timeless design with the term affective sustainability, conducted research, where participants were assigned to identify an object with such a quality. Few of them even “put themselves in an almost meditative stage to be able to come up with suggestions, which finally produced the right ‘gut feeling’.” (Börjesson, 2006, 2009) Feeling as a method of collecting data is an integral part of the phenomenological approach, e.g., in the qualitative study of experience and values of the historical environment (Wells-Baldwin, 2012).

The correlation between visual complexity and the wholeness of architectural form is strongly supported by the biophilia effect. This paper attempts to broaden the debate to the wholeness of the substance itself – the building material. The basic assumption is that material itself has its own implicate structure-preserving transformation which cannot be reduced to its superficial characteristics. Therefore, a question arises when we encounter materials convincingly mimicking the appearance of natural materials.

If we take into account the biophilia hypothesis assumption that a mere image of a natural landscape in a room can reduce physiological stress and increase comfort, then what is the case of synthetic or massively processed materials mimicking natural materials? Can a wood-like floor made from plastic have a healing effect for its nature evoking visual qualities? Is classicist façade made of polystyrene beautiful? Has melamine board with wooden décor life in it? These questions and their further implications regarding wholeness and life converge into the main research question of this paper:

Is the wholeness (or life) of structures reducible to the visual complexity?

3. Materials and methods

In the overview, chosen materials are presented and their relevance for answering the research question justified. To answer the research question and probe the assumption about the wholeness of the material, the issue of imitation and the term material authenticity is described in this section. To question the correlation between visual complexity and wholeness, a fractal dimension analysis and estimation of architectonic life are used for quantitative measurement and for estimating the wholeness (life) of the room images and material samples, the mirror-of-the-self test is employed in the survey. The methods used and their results are presented consecutively. Overall results are then discussed at the end of this paper.

Materials for this study are pictures of a room and material samples of flooring. The room has no apparent function and no furniture in it. Each of the pictures has a different floor design. The wooden floor (Fig. 1) was chosen deliberately for the innate nature evoking texture, and the floor pattern design was chosen to increase visual complexity and wholeness by some of the transformations of the living structure, (see Table 1). Fig. 2 shows a room flooring of a similar degree of visual complexity as Fig. 1, but not in a biomorphic manner but in abstract geometrical pattern. Fig. 3 represents a floor design with low visual complexity and no explicit nature evoking visual quality.

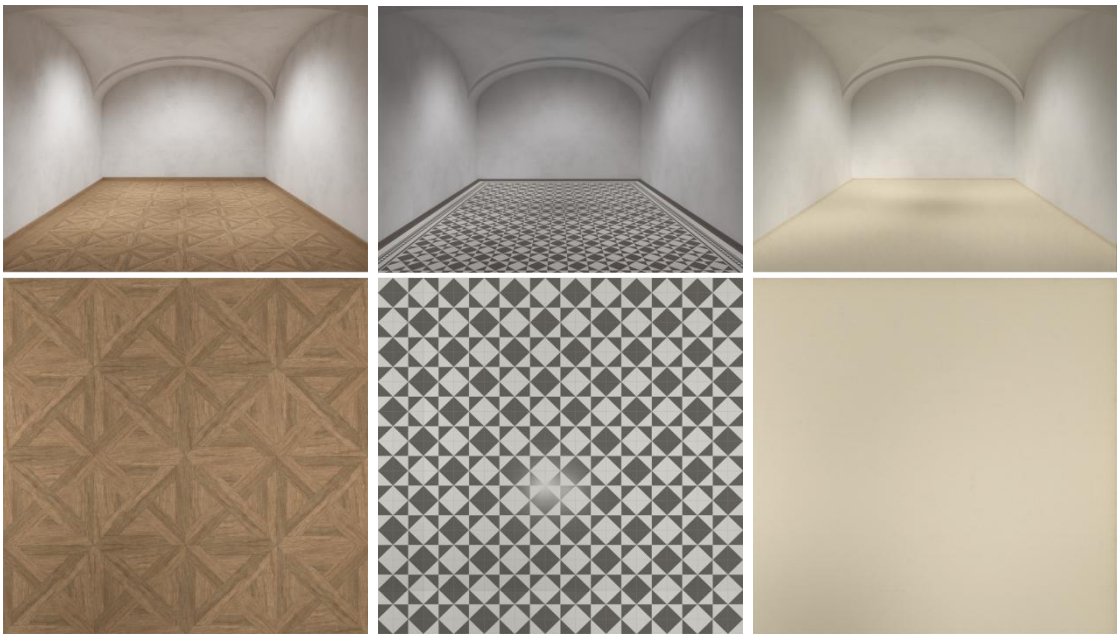


Figure 1. Wooden parquet

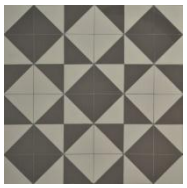
Figure 2. Ceramic tiles

Figure 3. Linoleum

A sample (1) of a wooden parquet floor is used as a referential sample. Samples (3) and (5) are chosen as imitations of the referential sample in different materials – ceramics and vinyl. All three samples have the visual representation of the application rendered in Fig. 1. Sample (2) has its representation in Fig. 2 and sample (4) in Fig.3.

At first, Figures 1-3 are analyzed for their visual complexity and then are used as subject matter for the mirror-of-the-self test along with the five material samples in Table 2. The list of material samples in Table 2 is accompanied by characteristics with a relative degree to each other. Quality of biomorphism is concerning the biophilia effect and material authenticity is concerning wholeness of material and it is addressed below. There are plenty of material properties which are not included in this evaluation such as durability, repairability, water resistance, patina, etc.

Table 2. Tab of the flooring material samples

Tab of the flooring materials and their characteristics relevant for comparison (relative on scale 1-3)				
	Flooring material	Description	Material authenticity*	Biomorphism (nature evoking)
1	Wooden parquet 	referential sample natural material with high authenticity and high visual complexity	3	3
2	Ceramic tiles 	different kind of natural material with high authenticity, and same or lower visual complexity as referential sample	3	1
3	Ceramic tiles 	different kind of natural material visually mimicking the referential sample	1	3
4	Linoleum 	different kind of natural material with lower authenticity and lower visual complexity than referential sample	2	1
5	Vinyl 	synthetic material visually mimicking the referential sample	1	3
(*Material authenticity is defined below in this Section and discussed in Section 9)				

According to Christopher Alexander, living structures emerge through the process of structure-preserving transformation. (Alexander, 2002-2005) To address the issue of material wholeness let's take, e.g., timber as a construction material. The form of solid wood has certain anisotropic properties we have to take into account and respect to use it properly in construction. It means we have to adapt to its peculiarities. On the contrary, in the case of, e.g., MDF board or hardboard, the timber is crushed to small pieces or dust and glued together, hence it is transformed non-adaptively with a great loss of its former structure. MDFs or melamine boards often receive a photograph of a wooden board texture or veneer on the surface. To address the degree of transformation it takes to

produce a material, I propose the term *material authenticity*. (with no connotation to the term authenticity in heritage preservation).

Material authenticity – a degree of preservation of the inner structure and surface texture of the original material extracted from the natural environment in the final material product.

By this definition, we can consider traditional construction materials such as stone, clay or wood, lime, or straw as of a high degree of material authenticity. To keep authenticity during production, we can accept transformations of the raw material by mechanical means such as cutting, bending, molding with little or no loss of material authenticity. Even chemical changes in the process of burning ceramics preserve many of the qualities of the clay. It takes more transformations to produce glass, steel, or cement, and still, they are commonly considered natural materials. On the contrary, the least authentic are materials considered as synthetic, because they need a long chain of processes and lose many of the properties of the input material such as petroleum.

Apart from the degree of transformation, material authenticity by definition reveals the issue of material imitation, which can be described as an intentional mimicking of different materials on a surface. We use the word "imitation" especially in cases that are very persuasive and intentionally pretending to "be something else". This mimicking of visual properties can conflict with haptic or acoustic sensory perception, and this inner discrepancy may be associated with cognitive dissonance. We can experience different degrees of "fakeness" compared to when we encounter ceramic tiles imitating stone, or ceramic tiles imitating wood, where the expected tactile perception differs much more from the visual.

To conclude, the selection of the materials was based on an assumption that imitation decreases the material authenticity and wholeness of the material due to the lower resemblance of self and being. Second aspect of material authenticity anticipates that highly processed materials, especially those going through structure-destroying transformation, can be alienating and therefore have a lower degree of wholeness.

4. Fractal dimension analysis

Fractal dimension as an indicator of visual complexity is defined as a dimension with a non-integer value. The most widely used method for fractal dimension analysis is the box-counting method. Even though the values of fractal dimension analysis may vary for methodological reasons, researchers agree upon the positive effects of the complex environment with intermediate fractal dimension (around D=1,5) (Salingaros, 2006). In recent architectural research, there can be found examples of measuring the complexity of mosque façades (Ediz & Ostwald, 2012; Ostwald & Ediz, 2015), a Hindu temple in Northern India (Rian et al., 2007), or a modern public building complex in a historical context (Lionar & Ediz, 2020). The specifics of the method and the multiplicity of variables influencing the results show that the most informative outcomes are those used for comparative purposes against some standard value.

For the comparative analysis of fractal dimension, a set of pictures was prepared to get the required data (table 3). In this study, we consider the room in the picture as the large scale, the pattern of flooring design as the middle scale, and the texture of the material as the small scale. Drawings and photographs were prepared in the black and white threshold. The texture of the walls in the picture was omitted due to the significant increase of complexity and possible distortion of the results.

The computation of the fractal dimension was processed by the box-counting method with the software ImageJ and plugin FracLac. The box-counting process consists of a number of iterations of grids containing boxes/cells of varying numbers and sizes that are superimposed over the preprocessed images. The sizes of the boxes are consecutively reduced according to the scaling coefficient (SC), which in this case is set for default linear (following the series 5, 9, 13, 17, 21…). The critical factor is the sufficient number of iterations required to produce an accurate result. Following the suggestion to use a minimum of eight and ideally ten iterations (Ostwald and Vaughan 2016), in this case, the number of ten iterations was applied. The minimal size of the box is set for 5 pixels, i.e., the size of the thickest line of the drawing. The methodological variables are described in a more detailed manner in various publications (Bovill, 1996; Lorenz, 2003; Ostwald & Vaughan, 2016; Ostwald & Ediz, 2015).

As a result, the final fractal dimension (D) is calculated as the average value of a number of D# values. These variable settings were tested on the test image of the same size as our images (Fig. 4) with known theoretical fractal dimension D=1,5. The result of the test image fractal analysis D=1,5072 with standard deviation σ=0,0189 validates the settings for use in this study.

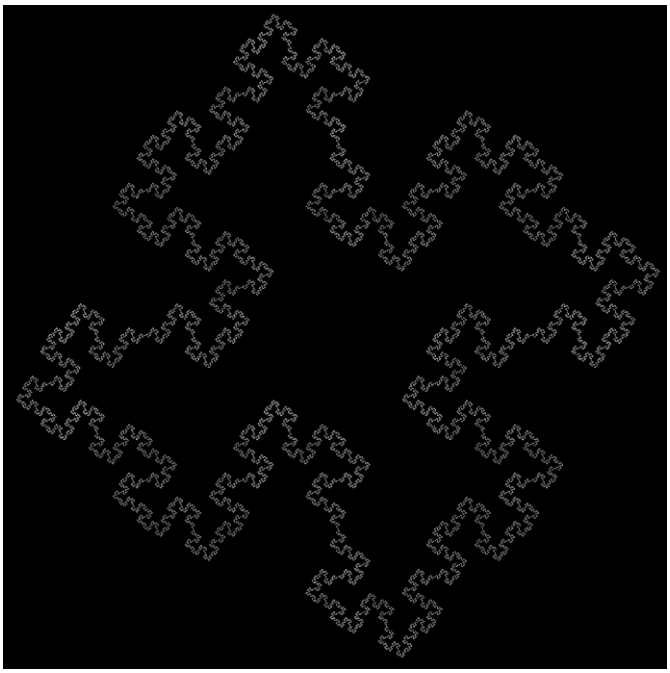
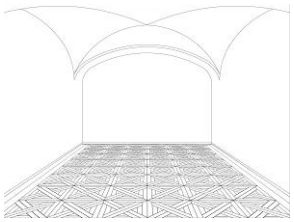
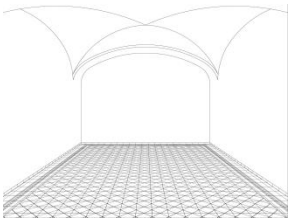
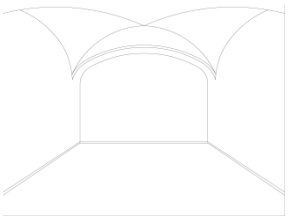
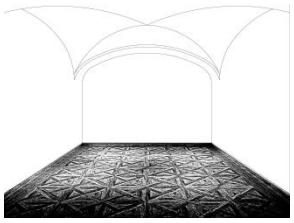
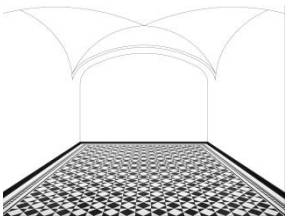
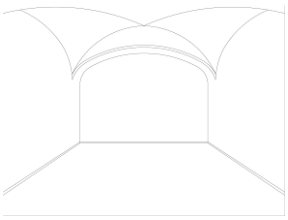
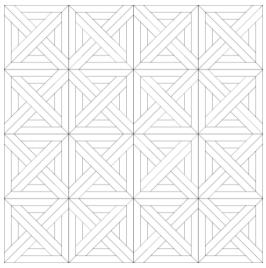
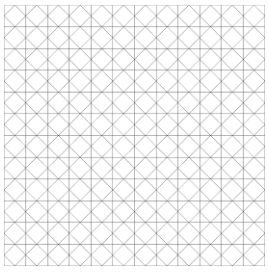
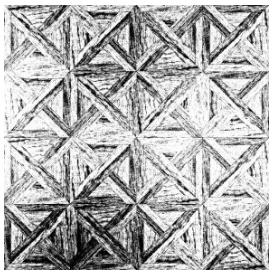
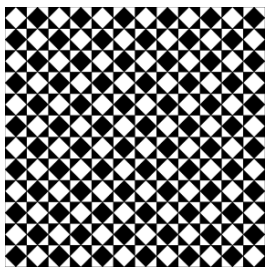


Figure 4. Test image with known theoretical fractal dimension D=1,5

Table 3 and Fig. 5 show the results of the fractal dimension analysis. The graph in Fig. 5 shows a gradual increase of the complexity with the scaling.

Layer (b) depicts a room with a floor design pattern showing large, middle, and small scale which has an appropriate level of detail for a quantitative comparison of the room view. Layer (d) depicts the material visual characteristics in detail of texture. Layers (a) and (c) exclude the small-scale details of material texture. Layers (a) and (b) are more relevant for comparison since the observer sees the whole room at once, whereas layers (c) and (d) are considered as additional.

Table 3. Results of fractal dimension analysis of the images with different levels of scale

A fractal dimension analysis of the images with different levels of scale				
		1	2	3
a	Drawing large scale middle scale			
	D	1,5544	1,5638	1,2414
b	Photo large scale middle scale small scale			
	D	1,6042	1,5822	1,2414
c	Drawing middle scale			
	D	1,7062	1,7188	
d	Photo middle scale small scale			
	D	1,8458	1,8056	1,7721

The main result from the fractal dimension analysis is quantitative data of similar complexity of the wooden floor and the ceramic tile floor design and significantly lower complexity of the linoleum floor. This has proven our intuitive impression about the level of complexity. Ostwald and Vaughan (2016) suggest that, for more than one object to be considered "highly similar" in terms of visual complexity, the difference must not exceed 1%. The room view (a) shows high similarity for wooden floor D=1,5544 and ceramic tile floor D=1,5638, with the standard deviation σ =0,03, and low similarity with the

linoleum floor D=1,2414. Layer (d) shows a high similarity of all three, even the texture of the linoleum floor without any middle scale.

Fig. 5 graphically renders how the view into the room (layers ‘a’ and ‘b’) with wooden floor and ceramic tiles takes place in the range of optimal fractality. Unlike the view into the room with the plain floor (3), or the detailed view on the floor pattern (layers ‘c’ and ‘d’). Additionally, the graph accentuates the lack of a middle scale of the plain floor (3).

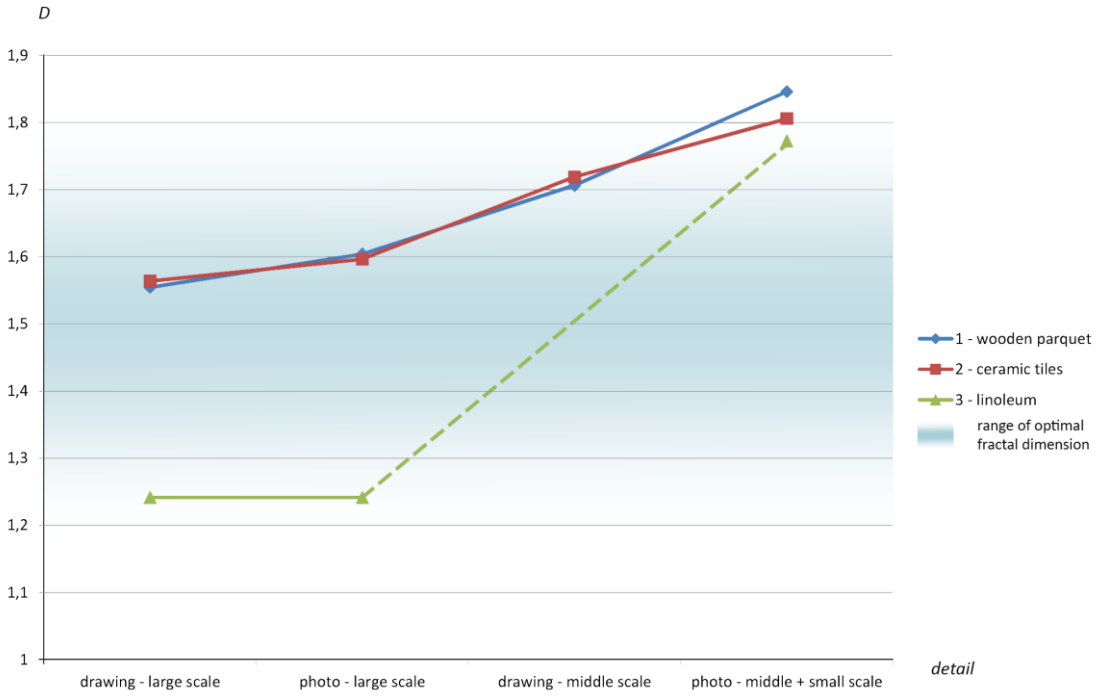


Figure 5. A graph rendering results from Table 3 showing the relationships between different levels of scale

5. Saligaros’s architectonic life

Salingaros developed a method for estimation of wholeness (life) in structures that has its numerical expression on the scale of 0–100. The method is based on the analysis of the 15 properties of living structure and is extensively described in his paper, first published as Life and Complexity in Architecture from a Thermodynamic Analogy (1997) and later reprinted as a chapter in A Theory of Architecture (2006), and The Unified Architectural Theory (2013). Salingaros claims a strong correlation to the results from the mirror-of-the-self test. For the reasons mentioned in Section 2, I use this method only for estimating the visual complexity of the images.

“(1) The architectural temperature T is defined as the degree of detail, curvature, and color in architectural forms; and (2) the architectural harmony H measures their degree of coherence and internal symmetry. This model predicts a building's emotional impact. The impression of how much life a building has is measured by the quantity L = TH (…)” (Salingaros, 1997).

Table 4. A numerical expression of architectonic life

architectural temperature variables			**architectural harmony variables**		
T_1	0-2	intensity and smallness of perceivable detail	H_1	0-2	vertical reflectional symmetries on all scales
T_2	0-2	density of differentiations	H_2	0-2	translational and rotational symmetries on all scales
T_3	0-2	curvature of lines	H_3	0-2	degree to which distinct forms have similar shapes
T_4	0-2	intensity of color hue	H_4	0-2	degree to which forms are connected piecewise
T_5	0-2	contrast among color hues	H_5	0-2	degree to which colors harmonize
T	0-10	T = T1 + ... + T5	H	0-10	H = H1 + ... + H5
architectural life					
L	0-100	L = TH			

Table 5. Results of architectonic life estimation on Fig.1-3

Tab of room images (Fig. 1-3) and their degree of architectonic life according to Salingaros													
Floor design	T_1	T_2	T_3	T_4	T_5	H_1	H_2	H_3	H_4	H_5	**T**	**H**	**L**
Wood parquet (Fig.1)	2	2	2	1	1	2	1	2	2	2	8	9	**72**
Ceramic tiles (Fig.2)	0	1	1	2	2	2	0	2	1	0	6	7	**42**
Linoleum (Fig.3)	1	0	1	0	1	1	1	1	1	2	3	6	**18**

6. Alexander's the mirror-of-the-self test

Christopher Alexander proposes his method in the first book of the series The Nature of Order – The phenomenon of life. (2002–2005) This comparative method aims to get a value judgment from respondents based on specific questions regarding the deep feeling of wholeness and life of their own being. There are always two subjects for comparing, and the respondent attempts to identify which one of them resonates more with their inner sense of being (or "I", self, wholeness, life). Any questions about liking, aesthetic preferences, or beauty are avoided. Ideally, the survey can deliver ego-less judgment avoiding culturally learned preferences and personal taste.

The mirror-of-the-self test is proposed as an empirical method of observation that includes the observer's inner world of feelings into account. By this turn in the scientific paradigm, Alexander develops a notion of a so-called post-Cartesian sense of objectivity and thereby can take the overall agreement of beauty as an objective fact. Alexander's method is not in contradiction with the Cartesian model unless we insist on the dualism of objective-subjective, which then becomes very limiting. Nevertheless, for methodological reasons, I chose to formally approach this method as a qualitative method providing universally shared subjective judgment.

According to Alexander, wholeness is a real structural phenomenon that demands us to see the whole, which is not an easy task when we try to focus attention. Therefore, an observation of inner feeling along with the observation of the structure is needed. We can find an analogy in hearing a piece of music. We can instantly judge whether the melody is out of tune without a musical education because we are intrinsically set for detecting (in)coherence. On the other hand, when we try to consciously pay attention to the listening, it is very hard not to listen to a particular melody or instrument and hear the

whole. To conclude, the feeling of coherence or the observation of it is the true aim of this method.

Variation of the method has been used, e.g., in a dissertation thesis by David Eyer (2016) from a complex perspective of building biology. Also, as mentioned in Section 2, Yodan Rofè developed a method of feeling maps based on Christopher Alexander's findings (Weinreb & Rofè, 2013; Rofè & Pontikis, 2016).

The mirror-of-the-self test is approached in analogy to a clinical interview – a specific form of conversation with standardized goals (analogous to confirmation or disapproval of diagnosis) but only by a partially standardized method. (Smith–Davis, 2000) The goal is to receive an answer with a considerable degree of certainty to the questions concerning the respondent's feelings. The objectives are settled and so is the set of questions, but the choice of the strategy lies with the interviewer. The interview can evolve and diverge when doubts about understanding the question occur or when answers are contradictory. The result – the collected data – is always a choice between two subjects. Questions on the visceral feeling of one's self require very concrete formulations, where each of them has its appropriateness and its limits. Only by changing the questions and points of view, we can dispel doubts, increase understanding of the questions, and avoid cognitive dissonance regarding the out-of comfort zone position. The interviewer chooses the kind of questions that the respondent is willing to answer and takes care to put them appropriately, meaning whether to emphasize the intimacy of experience and sincerity or easiness and lightheartedness.

The interview was conducted in person, one-to-one in a quiet place. The whole session took mostly about 45 minutes (from 30 up to 90) and has four phases. Questions (see Table 6) were formulated in accordance with the mirror-of-the-self (Alexander, 2002) with variations.

The first part is an introduction, where the respondent is properly informed about the session, its purpose, anonymity, and the general background of the topic.

The second phase consists of two "pretest" rounds of comparing objects – a pair of glasses and a pair of forks, where questions of the mirror-of-the-self (table 6) are probed extensively, and where the interviewer and respondents achieve a certain level of understanding. This "training" phase serves for preparing a respondent for the intimacy or weirdness of some question and to ensure which type of questions the respondent is willing to answer.

The third phase begins when a respondent is shown pictures Fig. 1–3 and is asked to compare those in pairs according to the questions in Table 6.

The fourth phase consists of comparing the material samples from Table 2. They are compared in pairs according to the same set of questions. Certain desired pairs are questioned with higher priority, some pairs are not asked, as they are not relevant to the research question. Some answers were not recorded, because the answers were too contradictory, or a considerable level of certainty was not reached, or due to the lack of respondents' concentration at the end of the survey.

During the third and fourth phase, where pictures and samples are compared, only a few questions from table 6 are used, usually 3–5 for each pair. When the question is answered, the interviewer asks for deeper motivations or the respondent's answer to be able to guide the attention behind the thoughts and ideas to the deep feeling and bodily response. When the answers are contradictory, a small discussion is held until a reasonable level of certainty is reached. Since the desired answer is not the first that comes to mind, some pairs are stayed longer or get back with afterward. After a few questions,

when the answers are not contradictory, the final choice (judgment about a higher degree of life or wholeness of one of the objects) is made. At the end of the survey, the whole set is gone through and a respondent is asked if they want to change some answers.

Table 6. The mirror-of-the-self test questionnaire

The mirror-of-the-self test questionnaire	
No.	Question
1	Which of the two objects is a better picture of your self? Picture of all what is yours, all the virtues and weaknesses, all your wishes and fears, all that you are and want to be?
2	Which of the two compared objects is a better image of your humanity? Which one better reflects your own love and anger, your vulnerability and nobility in a meaningful whole?
3	Which of the two objects would you rather give to your mother or any beloved person as a gift to express your love and care?
4	In a presence of which of the two objects do you feel more alive?
5	Which of the two objects raises more feeling of connectedness to the world and yourself?
6	Which of the two things would you rather become in your next life?
7	Which of the two things would you rather become the last day of your life?
8	Which of the two examples feels like expanding your humanity?
9	Thanks to which of the two you feel closer to God or you are more aware of God?
10	Thanks to which of the two examples you feel more integrity inside of you?
11	Your personality develops, your opinions and preferences change during your life. However, try to focus (or imagine) on the "I", a part of you that stays together with you for your entire life. Which of the two examples is better reflecting the timeless "I" in you?
12	Which of the two examples more awakes the unconditional love, or inspires it in you?
13	Which of the two makes you feel more interconnectedness (unity) of everything that is?
14	Which of the two objects would you choose to be yours (…) for the rest of your life?
15	Which of the two examples has more timelessness? Which one do you feel that outlasts the ever-changing fashions and trends more likely?
16	In a presence of which of these two examples do you feel more likely to be in a present moment, with your back straightened, your breath deepened? (Which one makes it easier?)
17	Which of the two examples resembles more soulfulness?

Table 7. The mirror-of-the-self test results

Tab with results of the mirror-of-the-self test														
subject		**pictures (figures)**			**material samples (from table 2)**									
pairs		**1-2**	**1-3**	**2-3**	**1-2**	**1-3**	**1-4**	**1-5**	**2-3**	**2-4**	**2-5**	**3-4**	**4-5**	**5-3**
Respondent number	R1	1	3	2	1			1	2	2	2	3	5	4
	R2	1	1	2	1	1		1	2	2		4	5	
	R3	1	1	2	1	3		5	2	2	2	3	5	
	R4	1	3	3	1	1		1	2	4	5	4	4	
	R5	1	1	2	1	1	1	1	2	2	2	3	4	5
	R6	1	1	2	1	1		1	2	2	2	3	4	
	R7	2	3	2	2	1	1	1	2	2	2	4	5	5
	R8	1	1	2	1	1	1	1	2	2	2	4	4	3
	R9	1	1	2	1	1	1	1	2	2	2	4	4	3
	R10	1	1	3	1			1	2	2	2	3	4	
	R11	1	1	3	1			1	3	2	5	4	5	
	R12	1	1	2	1	1	1	1	2	2	2	4	4	3
	R13	1	1	2	1	1	1	1	2	2	2	4	4	3
	R14	1	1	2	1	1	1	1	2	2	2	4	4	3

Table 8. Crucial pair comparison for answering the research question

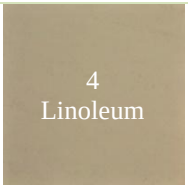
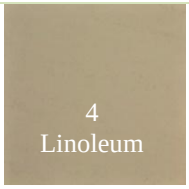
Table of the selected pairs crucial for answering the research question				
Which of the two floor samples has a higher degree of wholeness according to mirror-of-the-self test?				
1-2	3-2	5-2	3-4	5-4
93%	7%	21%	29%	36%
				
				
7%	93%	79%	71%	64%

Table 9. Representation of individual population groups

respondents' profile							
residents	**gender**		**age**			**architects**	
czechia	male	female	-30	31-50	51+	yes	no
14	6	8	10	3	1	4	10

None of the respondents were familiar with the notion of biophilia and Alexander's or Salingaros' theories. Respondents were not told the research question and the experimenter strictly avoided mentioning complexity, ornamentation and the like to prevent undesirable associations with the research question. Although these precautions ensure at least partial blinding, an unconscious bias was not treated.

Table 8 shows selected pair comparisons that are essential to answer the research question and examine the hypothesis about the material authenticity. The basic assumption that a wooden parquet floor would be considered as of the highest degree of wholeness was proved by the majority of respondents for both the picture of a room (93%) and the material sample (93%). The majority of respondents also considered the ceramic tile floor with black and white tessellation pattern as more living than the plain surface floor of linoleum. For the image, it was 79% and for the material sample 93%. These results are in accordance with the assumption that a higher degree of visual complexity is proportional to a degree of wholeness which was supported by a considerable majority.

The difference makes the comparison of material imitations in pairs of samples 2–3 and 2–5, where ceramic tile floor with black and white tessellation pattern with a bit lower degree of visual complexity was considered as more living than ceramic tile floor imitating wooden parquet by 93% or wood-like vinyl by 79% of respondents. This result supports the hypothesis that the degree of material authenticity has more importance than visual complexity regarding the question of wholeness.

Other key pair comparisons in this survey were 4-5 and 4-3, where highly processed materials were compared. More than half of the respondents consider the linoleum floor (4) more living (a higher degree of wholeness) than ceramic tile imitating wood (3) and vinyl floor imitating wood (5). Although the results of the mirror-of-the-self test, in this case, were not as decisive, we can interpret the results that the visual complexity did not play such a crucial role when it came to the contact with the material and observation of deep feeling.

7. Limitations

Any image can have its formal complexity measured by the fractal dimension analysis, even the images not necessarily having any fractal geometric qualities. (Ostwald–Vaughan, 2016, pp. 60) For that reason, I use this method only for comparative purposes. Furthermore, the distortion of images by conversion to black and white mode, excludes some properties such as color, contrast, gradients, etc.

The method of architectonic life estimation covers some of the limitations mentioned above by involving more qualitative aspects. On the other hand, it makes it less precise by involving subjective judgments.

There are also strong limits to the use of the mirror-of-the-self test. According to the theory of living structures, the quality arises from the whole arrangement, the whole situation, which demands a natural experiment. Nevertheless, the vivid images of a room combined with the real material samples are acceptable as a compromise for the test to be held. Christopher Alexander himself describes the limits of his method, especially in difficulties with western educated people to give up their ego to receive valid results. Also adds that for detecting life in structures, people need certain training. Regardless of these warnings, Alexander claims up to 80% agreement across populations.

However, since the method in this research did not provide agreement by a considerable majority in the cases of 4-5 and 4-3 pair comparison, reasonable doubt about the execution of the test can be brought up as well as the accuracy or usability of the method itself. Similarly unconvincing results provide Jou-Hsuan Wu (2015) in the application of the mirror-of-the-self-test in his master thesis research. During the mirror-of-the-self test, it was extremely difficult to guide respondents beyond their opinions, emotions, and experience from the past. Although double-blinding would formally ensure the internal validity, the experimenter would still need to use at least some privileged knowledge about distinguishing taste or mere liking from deeper feeling in order to guide the mirror-of-the-self test. Even though the reliability of the method in its current form is in question, so far, there is no other way to detect wholeness without analysis and reducing modeling, than to involve a conscious self in the process.

8. Discussion

The results have implications in the biophilic design and open up a question of material substance as a whole complex, rather than its visual properties. Quite paradoxically, e.g., vinyl floor with wooden décor can release a permitted amount of toxic chemicals, have massive ecological demand and still have a biophilic effect for its biomimetic appearance. Both linoleum and vinyl floor need a tremendous amount of transformations of the input material and that makes them sort of alienating (difficult to attach to). Some of the respondents described them as “just a piece of rubber. Unlike the

wood-like vinyl floor, the linoleum has extremely low visual complexity, but due to its biotic origin or not imitating texture, has a little more material authenticity. One of the assumptions regarding material authenticity was that human creativity affects the life of an object. Samples (1) and (2) manifest the original artistic capabilities of the creator, who can abstract order from natural forms and apply it in new patterns stimulating imagination. Although it may be fabricated in the line production, the designer's joy during the invention of the pattern is encoded in the result and therefore it can cause similar enjoyment to the user observing it. (Michl, 2020) On the contrary, the creativity and inventiveness of a realistic wood imitation in ceramics (Sample 3) or PVC (Sample 5) derives from an engineer's mind and may cause a quite different kind of enjoyment from successful task completion. Although the process of production may increase complexity and the result can have even biomorphic visual qualities, the process and the result are non-adaptive to the material itself and the human cognition.

Another query concerning biophilia comes up when comparing linoleum flooring (Sample 4) with the wood-like vinyl floor (Sample 5). Although linoleum has no explicit nature evoking pattern on a macro level, the texture visible on the surface is a result of the production and its homogenous appearance quite accurately indicates its physical properties and does not imitate some other material. Also, it is a CO^2 neutral material made from wood flour, pine tree, rosin, and natural pigments that makes linoleum indeed a nature-friendly material despite its demands for transformation of the input resources. On the contrary, the vinyl floor can mimic wood on the surface extremely well, with haptic details or warmth, but its production requires a lot more processing with the help of toxic chemicals and its negative impact on the environment is considerably bigger.

The material authenticity presented in this paper is a mere construct, but can be developed into a hypothesis in further research. In this study it serves to address some aspects of material wholeness based on the principle of structure-preserving transformations. The assumption mentioned in Section 2 is that material which is transformed during its production in an adaptive manner, meaning that preserves or respects its former structure, has a higher degree of wholeness (life). However, in the test respondents are asked to judge only the product itself and their experience with it. They do not necessarily need to be aware of the life cycle of the material and its transformations. The awareness of it could move the respondent's attention beyond the superficial appearance, but on the other hand, it could also involve more analytical thought process which is not desired. Nevertheless, what is obvious and can be observed (including all the senses) is the incoherence of the visual and material aspects in the case of imitations. As already mentioned, e.g. when ceramic or vinyl tile mimicking wooden parquet is approached, a confusion of senses or dissonance can be felt due to haptic or acoustic perception differing from the visual. One can also feel that when the tile is damaged, the crack or scratch would be different from the wood. In the case of massively processed (synthetic) materials one can avoid relating to it (feel alienated). Another aspect and possible explanation for the lack of connectedness to the physical could be also the absence of patina. Patina is a sign of physical changes due to aging and degradation which often manifest on the surface in the patterns of living structures such as *roughness, echoes,* or *not-separateness*. These material properties can resonate with our deepest experience of life and death. They are marks of adaptive transformations which inform us about being part of indivisible feedback loop with our environment. In this sense we can identify it with wrinkles on our own body and reflect our own transience. On the contrary, modern synthetic materials such as e.g. plastics are invented and made to sustain

a permanently new-like appearance and when they start to degrade they are often irreparable, sometimes unrecyclable, or incapable of aging beautifully. Even in Alexander's earlier work A Pattern Language, in the pattern *207 Good Materials* (Alexander, 1977, pp. 955–961), he comments trouble with 'modern materials' which needs huge machinery and generates identical pieces with lower ability to adapt and vary, which makes it impossible to reach an organic quality of natural buildings.

As the current paradigm of scientific materialism dominates the generally accepted world view, it is hard to address the notion of wholeness by Christopher Alexander, because it is so elusive regarding the description of causal relations and mechanisms. Even though his methods of deep feeling or mirror-of-the-self are considered as providing soft data of mere psychological responses, it can serve, for the time being, as a complementary and corrective tool for any of the attempts to quantify qualities such as beauty or life in structures which rely on visual representations.

There are new paths in science that do not rely strictly on materialistic determinism. Further scientific research in the theory of living structure could get support in e.g. in Rupert Sheldrake's notion of morphogenetic fields (Sheldrake, 2009) or the works addressing the hard problem of consciousness (body-mind relationship) by Daniel Hoffmann (2008), or David Bohm (1990). The differing world views of the right and left brain hemisphere that shapes our cultural framework is addressed in the works by psychiatrist by Ian McGilchrist (2009). For an exploration of values and value judgments, the ontology of subjectivity by philosopher Zdenek Neubauer (1999), or the map of consciousness by David Hawkins (2012) indicates a prolific discussion.

9. Conclusion

By methods of measuring fractal dimension and estimation of architectonic life, we obtained quantitative data about the relative degree of visual complexity of the images. Then a complementary qualitative method the mirror-of-the-self test confirmed the previous assumption that a higher degree of visual complexity is directly proportional to a degree of wholeness in the case of comparing images.

However, when the real material samples of imitations were compared, the results from the qualitative approach were in contradiction with the previous complexity-wholeness correlation. The results confirmed the assumption addressed in Section 2 that material authenticity has notable importance in the evaluation of wholeness. Therefore, the answer to the research question is that wholeness is not reducible to visual complexity. In other words, we can sum up that visual complexity analysis is a reductive scientific method that can provide some insights into the wholeness of structure, especially when evaluating visual representations, but cannot involve other non-visual factors, which can be of equal importance.

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