Perceived Wellbeing Effects of Designer Fractal Patterns: Visual Complexity and Interior Spaces

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This paper introduces my work-in-progress research into the perceived wellbeing effect – in particular through visual preference, visual interest and mood response – to fractal patterns in the built interior environment. The novelty of this research lies in the type of fractal patterns used as stimulus, which are inspired by a historical retrospective of wallpaper and upholstery fabric patterns. This work-in-progress aims to produce surface decorations that conform to a prevailing current aesthetic, but also bring into our spaces an ordered visual complexity, improving our psychological wellbeing and mood while maintaining our link with nature through practical biophilic design practices. This research aims to answer two questions: To what extent do the proven perceived wellbeing effects of statistical/natural fractals hold true for designer fractal patterns? In what ways are forced choice protocols beneficial when assessing perceived effects of the design of interiors, and what are the consequences of not utilizing methodologies that value ecological validity?

\textit{Keywords: fractal, interior design, biophilia, wellbeing}
1 Introduction
Although humans spend the majority of their time indoors, within built spaces, these interior spaces often suffer from banal blank forms and dull rigid lines. Our spaces address ADA regulations in terms of dimensions and ergonomics which but do not always address visual interest, visual preference, and mood as conditions of wellbeing. A curative approach may be found in opposing ‘careless’ design by making wellbeing a paramount factor, instead of becoming entrenched in ideological debates and novelty and forgetting the human element (Sagmeister & Walsh, 2018). Nowhere is this concept of wellbeing more important than within interior space, and that is why prioritizing it in interior spaces has been the aim of interior designers who understand the profound effect of the built environment on our psychological, physiological, and emotional wellbeing. A deeper awareness of the practical application of biophilic design practices among interior designers can lead to more stimulating spaces that enrich our wellbeing.

2 Biophilia’s Emotional, Physiological and Psychological Effects
Human affinity for nature, termed biophilia, has captivated designers interested in designing for wellbeing. The aim of these designers is to leverage the restorative effects of nature into interior spaces. The favourable impact can be categorized into psychological effect, physiological effect, and an aesthetic effect. Psychological effect can be understood as an increase in “… emotional restoration, with lower instances of tension, anxiety, anger, fatigue, confusion and total mood disturbance…” (Browning, Ryan, & Clancy, 2014, p.11). Positive physiological effects that occur when in the presence of nature include “…relaxation of muscles, as well as lowering of diastolic blood pressure and stress hormone levels in the bloodstream.” (Browning et al., 2014, p.11) The aesthetic effect of nature has been linked to an evolutionary system of processing natural elements. This system is titled Natural Information System (NIS). A positive aesthetic experience creates a positive emotional response that motivates us to inhabit a natural scene that is deemed hospitable (Joye, 2006).

The 14 patterns of biophilia (Browning et al., 2014) are an attempt to create an encompassing framework for all biophilic design. The theory of biophilia suggests that humans have always favoured nature in their environmental experiences. From physical plants and running water to natural analogues, such as feelings of refuge and serenity, nature has found its way into our built spaces. A clear benefit lies in expounding on a particular pattern’s practical application and real-world parallelisms for design education and practice.

My interest lies in expounding on a particular “biophilic condition” (Browning et al., 2014, p. 62), specifically the Nature Analogues category with a focus on order and complexity, which offers an opportunity for further study. Nature Analogues is an interesting focal point, because its focus on biophilic conditions created through “indirect evocations of nature” (Browning et al., 2014, p. 10). The condition of ‘Complexity and Order’, which is the focus of my investigation, has been described as having “Rich sensory information that adheres to a spatial hierarchy similar to those encountered in nature.” (Browning et al., 2014, p. 10). This condition of order and complexity is exemplified in fractal patterns seen in nature and architecture and provides a foundation for insights into biophilia’s emotional, physiological and psychological effects.
3 Fractals
Fractals were first categorized by Benoit Mandelbrot in his 1982 book “The Fractal Geometry of Nature.” To judge any geometric pattern as a fractal, it must demonstrate certain characteristics. The pattern must repeat, and its repetition must happen at different scales. Elements of the pattern must also be self-similar. It must also be infinite in its repetition (Parashar & Bandyopadhyay, 2014). The characteristics of fractals have been set out by the famed mathematician, Kenneth Falconer, to include (Falconer, 2003)

1. Fine structure, a cascade of detail
2. Irregular, hard to describe with Euclidian geometry
3. Self-similar, exact or statistical (mathematical or natural)
4. Can be described in a very simple way, recursion, translation, etc.

However, Falconer warns us against taking this list of characteristics as a hard and fast rule to decide what is ‘fractal’ and what is ‘non-fractal’. In fact, he compares the definition of ‘fractal’ to the definition of ‘life’ in biology. He says:

“The definition of a ‘fractal’ should be regarded in the same way as a biologist regards the definition of ‘life’. There is no hard and fast definition, but just a list of properties…it seems best to regard a fractal as a set that has properties … rather than to look for a precise definition which will almost certainly exclude some interesting cases.” (Falconer, 2003, p. xxv)

The natural world is filled with fractal patterns of different types and levels of complexity, these patterns are referred to as natural or statistical fractal patterns. Their abundance in nature gives humans have a strong evolutionary reason for processing them, resulting in an ease that is enjoyable and a ubiquity that is familiar (Joye, 2006).

Examples of mathematical (exact fractals) and natural (statistical fractals) can be seen in the images below.

Figure 1. Sierpinski's Triangle, an example of an exact mathematical fractal (Beojan Stanislaus, Wiki Commons) https://en.wikipedia.org/wiki/Sierpinski_triangle#/media/File:Sierpinski_triangle.svg
Joye comments on the abundance of fractal patterns in nature and their relationship to wellbeing in the following:

“While the fractality of nature has been amply demonstrated, there is now reason to believe that the presence of fractal geometry (in a sense) underlies these biophilic responses. To put it very crudely, it is not the tree that causes these emotional responses, but the fractal mathematics of the tree.” (Joye, 2007, p.318)

3.1 Wellbeing and Fractals
Biophilic design strategies, including the application of fractal patterns, promise a wellbeing effect on the inhabitants of space (Browning et al., 2014). More specifically, studies show a strong relationship between statistical (mathematical) fractals and wellbeing. The self-reported perceived wellbeing effects of fractal patterns have been documented as an increase in visual interest, visual preference, and mood (Abboushi, Elzeyadi, Taylor, & Sereno, 2019; Forsythe, Nadal, Sheehy, Cela-Conde, & Sawey, 2011). Other studies in laboratory settings have proven wellbeing effects in physiological effects of reduced heart rate and diastolic blood pressure, as well as a decrease in alpha brains of the brain (Abboushi et al., 2019; Bies, Blanc-goldhammer, Boydston, Taylor, & Sereno, 2016; Browning et al., 2014; Forsythe, Nadal, Sheehy, Cela-Conde, & Sawey, 2011; Hagerhall et al., 2008; Joye, 2007, 2011; R. P. Taylor, 2006; Williams & Aeon, 2017). In addition, evidence has shown that the fractal-wellbeing relationship is strongest with fractals of mid-range complexity, categorized by a fractal dimension of 1.3 -1.5 (Abboushi et al., 2019; Hagerhall et al., 2008; R. P. Taylor, 2006; Richard P. Taylor & Wise, 2002).
3.2 Fractal Complexity and Wellbeing

The level of complexity of fractals is measured through fractal dimension (D), which can range from 1.1 - 1.9. It is explained best in the following quote: "Fractals are typically characterized by a variable called the fractal dimension (D). This parameter quantifies the fractal scaling relationship between patterns at different magnifications. Based on the D value, fractals can be categorized into low (D=1.1-1.3), medium (D=1.3-1.5), and high complexity (D=1.5-1.9)." (Abboushi & Elzyadi, 2018, p. 2). A visual manifestation of these patterns in exact (mathematical)) fractal patterns, statistical (natural) fractal patterns, and hand-drawn patterns can be seen in Figure 3.

Figure 3. "Fractal complexity in nature, art and mathematics. The left column shows clouds with D = 1.3 (top) and a forest with D = 1.9 (bottom). The middle column shows Jackson Pollock’s Untitled 1945 with D = 1.1 (top) and Untitled 1950 with D = 1.89 (bottom)" Taylor et al., n.d., p. 7. The right column shows variance of D in a computer generated pattern, with a higher D in the bottom right pattern and a lower D in the top right pattern.

Figure 4. After (Abboushi et al., 2019, p. 60)

This preference for mid-range fractals is codified in Dr. Richard Taylor’s model of Fractal Fluency. A possible reason put forth by Taylor is that the human visual system is the most comfortable with mid-range fractals because they are the most prevalent in nature. He states: “Because many of nature’s fractals exhibit mid-range complexity, we proposed a ‘fractal fluency’ model for the human visual system in which it has adapted to efficiently process these mid-complexity patterns. The model [of fractal fluency] predicts that this
‘effortless looking’ will result in the enhanced performance of visual tasks [as an element of wellbeing]…” (Taylor et al., n.d.)

4 Fractals in Design

These findings, concerning midrange fractals and wellbeing, have clear implications for interior design specifically, and design generally. In fact, manifestations of fractal patterns are seen in the urban scale (macro), the architectural scale (middle), and the decorative interior scale (micro) (Kiani & Amiriparyan, 2016).

Some examples of these manifestations can be seen in the urban design of the African Ba-Ila villages (Eglash, n.d.) (See Fig 5).

![Figure 5. The above images show the fractal structure of the Ba-Ila villages (Eglash, nd) (https://homepages.rpi.edu/~eglash/eglash.dir/afractal/afarch.htm)](https://homepages.rpi.edu/~eglash/eglash.dir/afractal/afarch.htm)

Fractal repetition and scaling is common in Hindu temple design, and is a clear example of fractals in architecture (see Fig 6) (Salingaros, 2014).

![Figure 6. The fractal quality of self-similarity is clear in the forms of Indian temples. (after Iasef Md Rian) (Joye, 2011)](https://homepages.rpi.edu/~eglash/eglash.dir/afractal/afarch.htm)

At the microscale, fractal qualities can be seen in Islamic patterns, both 3D *muqarnas* and 2D tiling (Kaplan, 2011; Kiani & Amiriparyan, 2016).
Architecture theorist and Mathematician, Nikos Salingaros, asks an important question about complexity in design. The examples given of fractal design are often overwhelmingly traditional and historic. He traces the contemporary dearth of visual complexity to the living legacy of Modernism and the influential thoughts of Adolf Loos and Le Corbusier. On this issue, he comments:

“Thus they [Adolf Loos and Le Corbusier] condemned the material culture of mankind from all around the globe, accumulated over millennia. While these condemnations may seem actions of merely stylistic interest, in fact, they had indirect but serious consequences.” (Salingaros, 2004, p. 79)

Christopher Alexander, in his magnum opus, A Pattern Language, takes on the issue of ordering and patterning. Alexander champions ornamentation, or visual complexity, as “extra binding energy” (Alexander, Ishikawa, Silverstein, & Al., 1977, p. 1151) that helps connects elements of a building at the micro scale.

The idea of a perceptible scale is one that reemerges with other researchers. In order to leverage the possible benefits of biophilic fractal patterns to our wellbeing, the scale of fractal implementations must correspond to the human experience. The urban scale and architectural scale are not easily perceived by the inhabitants. When immersed in a built environment, interior space is the readily perceivable scale. The smallest scale of fractal manifestation – surface decoration and ornamentation – would be the most impactful, since it is readily perceivable and most immersive of all the scales. Joye speaks to the importance
of scale, adding that intentionality of the designer in incorporating fractal pattern is critical (Joye, 2011). The author introduces both these ideas leading to an amended set of characteristics that describe fractals in design:

1. Fine structure, a cascade of detail
2. Irregular, hard to describe with Euclidian geometry
3. Self-similar, exact or statistical (mathematical or natural)
4. Can be described in a very simple way, recursion, translation, etc.
5. Intentionally applied
6. Scaled iteration
7. 3 time nested iteration of shapes

The author proposes to call fractal patterns that follow the above characteristics ‘designer fractals’.

5 Methodology
To investigate the validity of these ideas, the following questions will be addressed in this research:

- Q 1: To what extent do the proven perceived wellbeing effects of statistical/natural fractals hold true for designer fractal patterns?
- Q 2: In what ways are forced choice protocols beneficial when assessing perceived effects of the design of interiors? What are the consequences of not utilizing methodologies that value ecological validity?

The disconnection between scientific data and practical application in design-related research can be investigated using a cross-disciplinary approach using cognitive psychology, environmental psychology, and physics. The aim of this approach is to show a connection between fractal patterns and positive wellbeing experiences (Bies, Blanc-goldhammer, Boydston, Taylor, & Sereno, 2016; Hagerhall et al., 2008; Taylor, 2006). However, the findings of such research are rarely incorporated into design practice. Firstly, the disconnect is due to the limited application scenarios that a designer can imagine from dry data. Secondly, the patterns used as stimuli in these scientific experiments, though providing the necessary visual complexity, do not conform to what a designer would consider aesthetically pleasing. On occasion, the fractal patterns used are drawn from line graphs showing market fluctuations as shown in Figure 8.

Figure 8. Fractal pattern used as visual stimulus in Hagerhall, et al. 2008, p.1491. This pattern is not one designers would consider aesthetically pleasing.
In my research, I address this disconnection in two ways. One, by using designer fractal patterns, in context within an interior environment, to measure and record the perceived wellbeing effects - in particular, to record positive vs. negative mood, visual interest, and visual preference. Examples of the designer fractal pattern I hope to use as visual stimuli in my research can be seen in Figure 9 and 10.

The second way I address the disconnect is by utilizing two different approaches to the methodology.

6 Steps Forward

The research plan includes two sessions that I will conduct.

The sessions are designed to collect responses to perceived wellbeing indicators: visual interest, visual preference and mood responses. The first session will enlist participants in a laboratory type experiment to rate the perceived wellbeing effects of several pattern swatches through a forced choice procedure, answering a prompt relating to each of the wellbeing indicators. The methodology is constructed to parallel the methodology used in precedence studies. Wherever a forced choice method would not be appropriate, a Likert scale will be used.

This second session will embrace a participatory mindset and prioritize ecological validity. The designer fractal patterns will be projected to cover an entire wall within a room. The participants in the room will be asked to communicate their perceived wellbeing. Several mapping activities will be carried out to establish responses to visual interest, visual preference and mood responses. Other responses will also be collected in this session such as spontaneous utterances, and observable behaviours.
7 References


**Author's name:** Noor Danielle Murteza is an MFA Candidate in the Design Department at The Ohio State University. She holds a BA in Interior Architecture and Design. Her research explores biophilic design in intersection with fractal patterning, in an effort to increase wellbeing in built environments.

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