# POLLOCK, MONDRIAN AND NATURE: RECENT SCIENTIFIC INVESTIGATIONS


***Richard Taylor***
University of Oregon,
email: rpt@darkwing.uoregon.edu


## ABSTRACT


The abstract paintings of Piet Mondrian and Jackson Pollock are traditionally regarded as representing opposite ends of the diverse visual spectrum of Modern Art. In this article, I present an overview of recent scientific research that investigates the enduring visual appeal of these paintings.


## INTRODUCTION

Walking through the Smithsonian (USA), it is clear that the stories of Piet Mondrian (1872-1944) and Jackson Pollock (1912-56) present startling contrasts. First, I come across an abstract painting by Mondrian called "Composition With Blue and Yellow" (1935). It consists of just two colors, a few black lines and an otherwise uneventful background of plain white (see Fig. 1). It's remarkable, though, how this simplicity catches the eye of so many passers-by. According to art theory, Mondrian's genius lay in his unique arrangement of the pattern elements, one that causes a profound aesthetic order to emerge triumphantly from stark simplicity. Carrying on, I come across Pollock's "Number 3, 1949: Tiger" (See Fig. 2). Whereas Mondrian's painting is built from straight, clean and simple lines, Pollock's are tangled, messy and complex. This battlefield of color and structure also attracts a crowd, mesmerised by an aesthetic quality that somehow unites the rich and intricate splatters of paint.

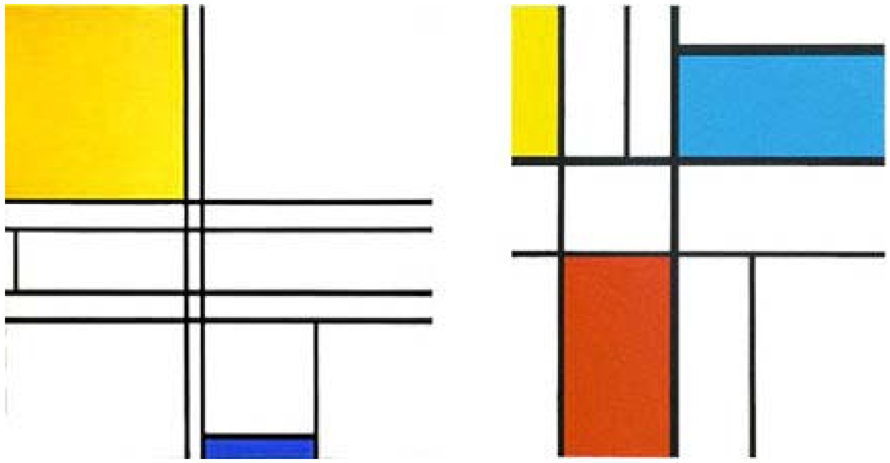


Figure 1. A comparison of Piet Mondrian’s “Composition with Blue and Yellow” (1935) with a painting by Alan Lee in which the lines are positioned randomly. Can you tell which is the real Mondrian painting?

Figure 2. Jackson Pollock’s “Number 3, 1949: Tiger.”

Both men reached their artistic peak in New York during the 1940s. Although Mondrian strongly supported Pollock, their approaches represented opposite ends of the spectrum of abstract art. Whereas Mondrian spent weeks deliberating the precise arrangement of his patterns [Deicher, 1995], Pollock dashed around his horizontal canvases dripping paint in a fast and spontaneous fashion [Varnedoe et al, 1998]. Despite their differences in the creative process and the patterns produced, both men maintained that their goal was to venture beyond life's surface appearance by expressing the aesthetics of nature in a direct and profound manner. At their peak, the public viewed both men's abstract patterns with considerable scepticism, failing to see any connection with the natural world encountered during their daily lives. Of the two artists, Mondrian was given more credence. Mondrian was a sophisticated intellectual and wrote detailed essays about his carefully composed works. Pollock, on the other hand, was frequently drunk and rarely justified his seemingly erratic motions around the canvas.

Fifty years on, both forms of abstract art are regarded as masterpieces of the Modern era. What is the secret to their enduring popularity? Did either of these artists succeed in their search for an underlying aesthetic quality of life? In light of the visual contrast offered by the two paintings at the Smithsonian, it's remarkable how the passers-by use similar language to discuss their aesthetic experiences. Both paintings are described in terms of 'balance,' 'harmony' and 'equilibrium.' The source of this subtle order seems to be enigmatic, however. None of the gallery audience can define the exact quality that appeals to them. It's tempting to come away from this scene believing that, half a century after their deaths, we might never comprehend the mysterious beauty of their compositions.

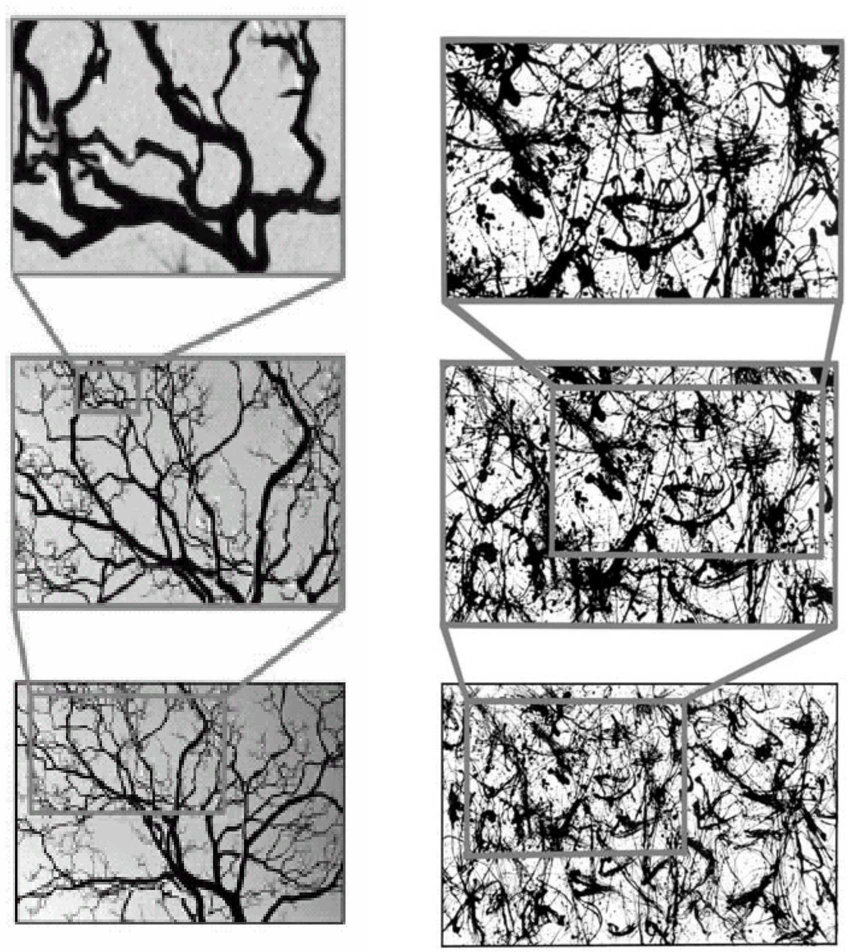
Recently, however, their work has become the focus of unprecedented scrutiny from an unexpected source - science. In 1999, I published a pattern analysis of Pollock's work, showing that the visual complexity of his paintings is built from fractal patterns –patterns that are found in a diverse range of natural objects [Taylor et al, 1999]. Furthermore, in an on-going collaboration with psychologists, visual perception experiments reveal that fractals possess a fundamental aesthetic appeal [Taylor, 2001]. How, then, should we now view Mondrian's simple lines?

## 1. Pollock's Dripped Complexity

First impressions of Pollock's painting technique are striking, both in terms of its radical departure from centuries-old artistic conventions and also in its apparent lack of sophistication! Purchasing yachting canvas from his local hardware store, Pollock simply rolled the large canvases (up to five meters long) across his studio floor. Even the traditional painting tool - the brush - was not used in its expected capacity: abandoning physical contact with the canvas, he dipped the brush in and out of a can and dripped the fluid paint from the brush onto the canvas below. The uniquely continuous paint trajectories served as 'fingerprints' of his motions through the air. During Pollock's era, these deceptively simple acts fuelled unprecedented controversy and polarized public opinion of his work: Was he simply mocking artistic traditions or was his painting 'style' driven by raw genius?

Over the last fifty years, the precise meaning behind his infamous swirls of paint has been the source of fierce debate in the art world [Varnedoe et al, 1998]. Although Pollock was often reticent to discuss his work, he noted that, "My concerns are with the rhythms of nature" [Varnedoe et al, 1998]. Indeed, Pollock's friends recalled the many hours that he spent staring out at the countryside, as if assimilating the natural shapes surrounding him [Potter, 1985]. But if Pollock's patterns celebrate nature's 'organic' shapes, what shapes would these be? Since the 1970s many of nature's patterns have been shown to be fractal [Mandelbrot, 1977]. In contrast to the smoothness of artificial lines, fractals consist of patterns that recur on finer and finer scales, building up shapes of immense complexity. Even the most common fractal objects, such as the tree shown in Fig. 3(a), contrast sharply with the simplicity of artificial shapes.

The unique visual complexity of fractal patterns necessitates the use of descriptive approaches that are radically different from those of traditional Euclidian geometry. The fractal dimension, D, is a central parameter in this regard, quantifying the fractal scaling relationship between the patterns observed at different magnifications [Mandelbrot, 1977, Gouyet, 1996]. For Euclidean shapes, dimension is a familiar concept described by integer values of 0, 1, 2 and 3 for points, lines, planes, and solids respectively. Thus, a smooth line (containing no fractal structure) has a D value of 1, whereas a completely filled area (again containing no fractal structure) has a value of 2. For the repeating patterns of a fractal line, D lies between 1 and 2. For fractals described by a D value close to 1, the patterns observed at different magnifications repeat in a way that builds a very smooth, sparse shape. However, for fractals described by a D value closer to 2, the repeating patterns build a shape full of intricate, detailed structure. Figure 4 demonstrates how a fractal pattern's D value has a profound effect on its visual appearance. The two natural scenes shown in the left column have D values of 1.3 (top) and 1.9 (bottom). Table 1 shows D values for various classes of natural form.



(a) (b)

Figure 3. (a) Trees are an example of a natural fractal object. Although the patterns observed at different magnifications don't repeat exactly, analysis shows them to have the same statistical qualities (photographs by R.P. Taylor). (b) Pollock's paintings (in this case "Number 32, 1950") display the same fractal behavior.

The patterns of a typical Pollock drip painting are shown at different magnifications in Fig. 3(b). In 1999, my research team published an analysis of 20 of Pollock's dripped paintings showing them to be fractal [Taylor et al, 1999]. We used the well-established 'box-counting' method, in which digitized images of Pollock paintings were covered with a computer-generated mesh of identical squares. The number of squares, N(L), that contained part of the painted pattern were then counted and this was repeated as the size, L, of the squares in the mesh was reduced. The largest size of square was chosen to match the canvas size (L~2.5m) and the smallest was chosen to match the finest paint work (L~1mm). For fractal behavior, N(L) scales according to $N(L) \sim L^{-D}$, where $1 < D < 2$ [Gouyet, 1996]. The D values were extracted from the gradient of a graph of log N(L) plotted against log L (details of the procedure are presented elsewhere [Taylor et al, 1999]).

**Table 1. D values for various natural fractal patterns**

| Natural pattern | Fractal dimension | Source |
|---|---|---|
| Coastlines:<br>South Africa, Australia, Britain<br>Norway | <br>1.05-1.25<br>1.52 | <br>Mandelbrot<br>Feder |
| Galaxies (modeled) | 1.23 | Mandelbrot |
| Cracks in ductile materials | 1.25 | Louis et al. |
| Geothermal rock patterns | 1.25-1.55 | Campbel |
| Woody plants and trees | 1.28-1.90 | Morse et al. |
| Waves | 1.3 | Werner |
| Clouds | 1.30-1.33 | Lovejoy |
| Sea Anemone | 1.6 | Burrough |
| Cracks in non-ductile materials | 1.68 | Skejltorp |
| Snowflakes (modeled) | 1.7 | Nittman et al. |
| Retinal blood vessels | 1.7 | Family et al. |
| Bacteria growth pattern | 1.7 | Matsushita et al. |
| Electrical discharges | 1.75 | Niemyer et al. |
| Mineral patterns | 1.78 | Chopard et al. |

Recently, I described Pollock's style as ‘Fractal Expressionism’ [Taylor et al, Physics World, 1999] to distinguish it from computer-generated fractal art. Fractal Expressionism indicates an ability to generate and manipulate fractal patterns *directly*. How did Pollock paint such intricate patterns, so precisely and do so 25 years ahead of the scientific discovery of fractals in natural scenery? Our analysis of film footage taken in 1950 reveals a remarkably systematic process [Taylor et al, Leonardo, 2002]. He started by painting localized islands of trajectories distributed across the canvas, followed by longer, extended trajectories that joined the islands, gradually submerging them in a dense fractal web of paint. This process was very swift, with D rising sharply from 1.52 at 20 seconds to 1.89 at

47 seconds. We label this initial pattern as the ‘anchor layer’ because it guided his subsequent painting actions. He would revisit the painting over a period of several days or even months, depositing extra layers on top of this anchor layer. In this final stage, he appeared to be fine-tuning D, with its value rising by less than 0.05. Pollock's multi-stage painting technique was clearly aimed at generating high D fractal paintings [Taylor et al, Leonardo, 2002].

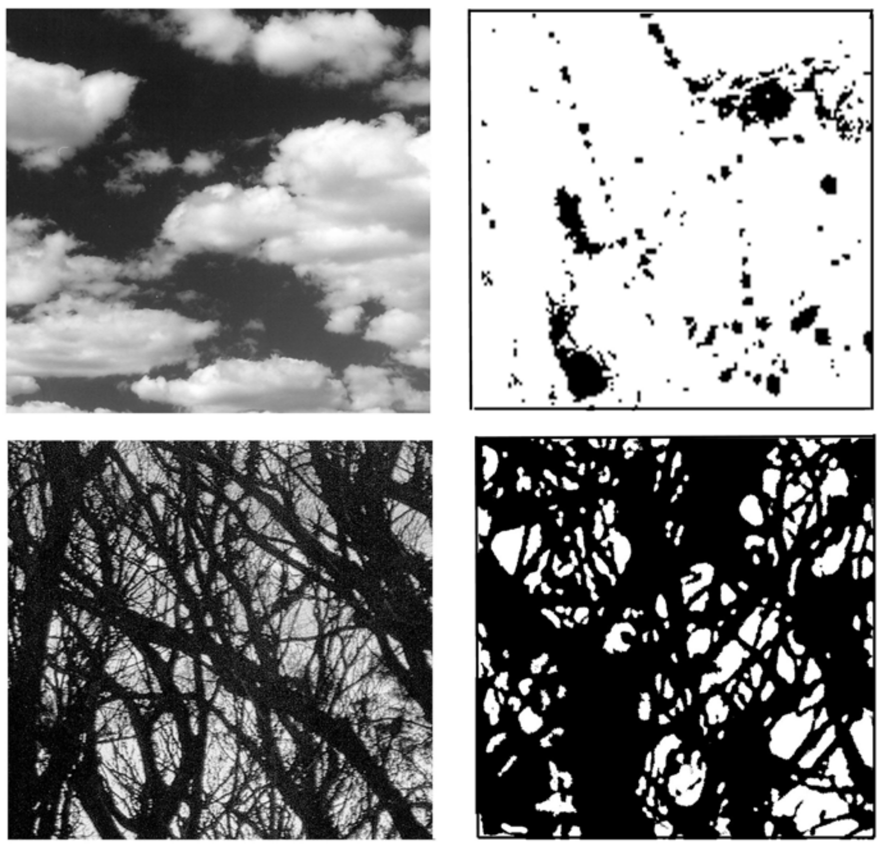


Figure 4. Examples of natural scenery (left column) and drip paintings (right column). Top: Clouds and Pollock's painting *Untitled* (1945) are fractal patterns with D=1.3. Bottom: A forest and Pollock's painting *Untitled* (1950) are fractal patterns with D=1.9. (Photographs by R.P. Taylor).

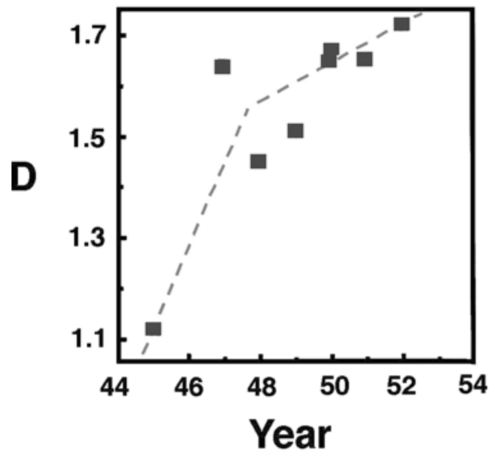



Figure 5. The fractal dimension D of Pollock paintings plotted against the year that they were painted (1944 to 1954). See text for details.

He perfected this technique over a ten-year period, as shown in Fig. 5. Art theorists categorize the evolution of Pollock's drip technique into three phases [Varnedoe, 1998]. In the 'preliminary' phase of 1943-45, his initial efforts were characterized by low D values. An example is the fractal pattern of the painting *Untitled* from 1945, which has a D value of 1.3 (see Fig. 4). During his 'transitional phase' from 1945-1947, he started to experiment with the drip technique and his D values rose sharply (as indicated by the first dashed gradient in Fig. 5). In his 'classic' period of 1948-52, he perfected his technique and D rose more gradually (second dashed gradient in Fig. 5) to the value of D = 1.7-1.9. An example is *Untitled* from 1950 (see Fig. 4), which has a D value of 1.9. Whereas this distinct evolution has been proposed as a way of authenticating and dating Pollock's work [Taylor, Scientific American, 2002] it also raises a crucial question for visual scientists - do high D value fractal patterns possess a special aesthetic quality?

## 2. FRACTAL AESTHETICS

Fractal images have been widely acknowledged for their instant and considerable aesthetic appeal [see, for example, Peitgen et al, 1986, Mandelbrot, 1989, Briggs, 1992, Kemp, 1998]. However, despite the dramatic label “the new aesthetic” [Richards, 2001], and the abundance of computer-generated fractal images that have appeared since the early 1980s, relatively few quantitative studies of fractal aesthetics have been conducted. In 1994, I used a chaotic (kicked-rotor) pendulum to generate fractal and non-fractal drip-paintings and, in the perception studies that followed, participants were shown one fractal and one non-fractal pattern (randomly selected from 40 images) and asked to state a preference [Taylor 1998, Taylor, Art and Complexity, 2003]. Out of the 120 participants, 113 preferred examples of fractal patterns over non-fractal patterns, confirming their powerful aesthetic appeal.

Given the profound effect that D has on the visual appearance of fractals (see Fig. 4), do observers base aesthetic preference on the fractal pattern's D value? Using computer-generated fractals, investigations by Deborah Aks and Julien Sprott found that people expressed a preference for fractal patterns with mid-range values centered around D = 1.3 [Sprott, 1993, Aks and Sprott, 1996]. The authors noted that this preferred value corresponds to prevalent patterns in natural environments (for example, clouds and coastlines) and suggested that perhaps people's preference is actually 'set' at 1.3 through a continuous visual exposure to patterns characterized by this D value. However, in 1995, Cliff Pickover also used a computer but with a different mathematical method for generating the fractals and found that people expressed a preference for fractal patterns with a high value of 1.8 (Pickover, 1995), similar to Pollock's paintings. The discrepancy between the two investigations suggested that there isn't a 'universally' preferred D value but that aesthetic qualities instead depend specifically on how the fractals are generated.

The intriguing issue of fractal aesthetics was reinvigorated by our discovery that Pollock's paintings are fractal: In addition to fractals generated by natural and mathematical processes, a third form of fractals could be investigated – those generated by humans. To determine if there are any 'universal' aesthetic qualities of fractals, we performed experiments incorporating all three categories of fractal pattern: fractals formed by nature's processes (photographs of natural objects), by mathematics (computer simulations) and by humans (cropped images of Pollock paintings) [Taylor, 2001]. Figure 4 shows some of the images used (for the full set of images, see Spehar et al, 2003). Within each category, we investigated visual appeal as a function of D using a 'forced choice' visual preference technique: Participants were shown a pair of images with different D values on a monitor and asked to choose the most "visually appealing." Introduced by Cohn in 1894, the forced choice technique is well-established for securing value judgments [Cohn, 1894]. In our experiments, all the images were paired in all possible combinations and preference was quantified in terms of the proportion of times each image was chosen. The experiment, involving 220 participants, revealed a distinct preference for mid-range fractals (D=1.3 –1.5), irrespective of their origin (Spehar et al, 2003).

The ‘universal’ character of fractal aesthetics was further emphasized by a recent investigation showing that gender and cultural background of participants did not significantly influence preference [Abrahams et al, 2003]. Furthermore, based on experiments performed at NASA-Ames laboratory, our recent preliminary investigations indicate that preference for mid-range D fractals extends beyond visual perception: skin conductance measurements showed that exposure to fractal art with mid-range D values also significantly reduced the observer’s physiological responses to stressful cognitive work [Taylor et al, 2003, Wise et al, 2003].

Skin conductance measurements might appear to be a highly unusual tool for judging art. However, our preliminary experiments provide a fascinating insight into the impact that art can have on the observer’s physiological condition. It would be intriguing to apply this technique to a range of fractal patterns appearing in art, architecture and archeology: Examples include the Nasca lines in Peru (pre-7$^{th}$ century) [Castrejon-Pita et al, 2003], the Ryoanji Rock Garden in Japan (15$^{th}$ century) [Van Tonder et al, 2002], Leonardo da Vinci’s sketch *The Deluge* (1500) [Mandelbrot, 1977], Katsushika Hokusai’s wood-cut print *The Great Wave* (1846) [Mandelbrot, 1977], Gustave Eiffel’s tower in Paris (1889) [Schroeder, 1991], Frank Lloyd Wright’s Palmer House in Michigan (1950) [Eaton, 1998], and Frank Gehry’s proposed architecture for the Guggenheim Museum in New York (2001) [Taylor, 2001, Taylor, New Architect, 2003].

As for Pollock, is he an artistic enigma? According to our results, the low D patterns painted in his earlier years should be more relaxing than his later *classic* drip paintings. What was motivating Pollock to paint high D fractals? Perhaps Pollock regarded the visually restful experience of a low D pattern as too bland for an artwork and wanted to keep the viewer alert by engaging their eyes in a constant search through the dense structure of a high D pattern. We are currently investigating this intriguing possibility by performing eye-tracking experiments on Pollock’s paintings, which are assessing the way people visually assimilate fractal patterns with different D values.

## 3. MONDRIAN’S SIMPLICITY

Whereas the above research is progressing rapidly toward an appealing explanation for the enduring popularity of Pollock’s paintings, the underlying aesthetic appeal is based on complexity. Clearly, Mondrian's simple visual 'language' of straight lines and primary colors plays by another set of rules entirely. In fact, Mondrian developed a remarkably rigorous set of rules for assembling his patterns and he believed that they had to be followed meticulously for his paintings to display the desired visual quality. The crucial rules concerned the basic grid of black lines, which he used as an artistic 'scaffold' to build the appearance of the painting. Mondrian used only horizontal and vertical lines, which he believed "exist everywhere and dominate everything." In one of the more notorious exchanges in Modern Art history, he argued fiercely when colleague Theo Van Doesburg proposed that they should also use diagonal lines. Mondrian passionately believed that the diagonal represented a disruptive element that would diminish the painting's balance. So strong was his belief that he threatened to dissolve the 'De Styl' art movement that had formed around his painting style. Mondrian wrote to him declaring, "Following the high-handed manner in which you have used the diagonal, all further collaboration between us has become impossible."

Although Mondrian's theory of line orientation has legendary status within the art world, only recently have his aesthetic beliefs been put to the test. Whereas Pollock's paintings are being used as novel test beds for examining peoples' responses to visual complexity, scientists are becoming increasingly interested in Mondrian's paintings because of their visual simplicity. In terms of neurobiology, it is well-known that different brain cells are used to process the visual information of a painting containing diagonal lines than for one composed of horizontal and vertical lines [Zeki, 1999]. However, as neurologist Semir Zeki points out, whether these changes in brain function are responsible for the observer's aesthetic experience is "a question that neurology is not ready to answer" [Zeki, 1999]. In 2001, one of my collaborators, Branka Spehar, performed visual perception experiments aimed at directly addressing the link between line orientation and aesthetics. She used images generated by tilting 3 Mondrian paintings at different orientations [Spehar, 2001, Taylor, Nature, 2002]. The 4 orientations included the original one intended by Mondrian, and also 2 oblique angles for which the lines followed diagonal directions. Spehar showed each picture through a circular window that hid the painting's frame. This removed any issues relating to frame orientation, allowing the observer to concentrate purely on line orientation. Using the 'forced choice' technique, she then paired the 4 orientations of each painting in all possible combinations and asked 20 people to express a preference within each pair. The results revealed that people show no aesthetic preference between the orientations featuring diagonal lines and those featuring horizontal and vertical lines. Spehar's results clearly question the importance of Mondrian's vertical-horizontal line rule.

Mondrian’s obsession with the orientation of his lines extended to their position on the canvas. He spent long periods of time shifting a single line back and forth within a couple of millimetres, believing that a precise positioning was essential for capturing an aesthetic order that was “free of tension” [Deicher, 1995]. Australian artist Alan Lee recently used visual perception experiments to test Mondrian’s ideals [Lee, 2001, Taylor, Nature, 2002]. Lee created 8 of his own paintings based on Mondrian’s style. However, he composed the patterns by positioning the lines randomly. He then presented 10 art experts and over 100 non-experts with 12 paintings and asked them to identify the 4 of Mondrian’s carefully composed patterns and the 8 of his random patterns (see Fig. 1). Lee’s philosophy was simple – if Mondrian’s carefully located lines delivered an aesthetic impact beyond that of randomly positioned lines, then it should be an easy task to select Mondrian’s paintings. In reality, both the experts and non-experts were unable to distinguish the two types of pattern. Line positioning doesn't influence the visual appeal of the paintings!

Could this surprising result mean that, despite Mondrian’s time-consuming efforts, his lines were nevertheless random just like Lee’s? To test this theory, I performed a pattern analysis of 22 Mondrian paintings and this showed that his lines are *not* random. For random distributions, each line has an equal probability of being located at any position on the canvas. In contrast, my analysis of 170 lines featured in the 22 paintings show that Mondrian was twice as likely to position a line close to the canvas edge as he was to position it near the canvas center [Taylor, 2003]. In addition to dismissing the ‘random line theory,’ this result invites comparisons with traditional composition techniques. In figurative paintings, artists rarely position the center of focus close to the canvas edge because it leads the eye’s attention off the canvas. If Mondrian’s motivations were to apply this traditional rule to his line distributions, he would have avoided bunching his lines close to the edges. Another compositional concept applied to traditional artworks is the Golden Ratio (sometimes referred to by artists as the “Divine Proportion”). According to this rule, the aesthetic quality of a painting increases if the length and height of the rectangular canvas have the ratio of 1.61 (a number derived from the Fibonacci sequence). Whereas the shapes of Mondrian’s canvases don’t match this ratio, a common speculation is that he positioned his intersecting lines such that the resulting rectangles satisfy the Golden Ratio. However, this claim has recently been dismissed in a book that investigates the use of the Golden Ratio in art [Livio, 2002].

## 4. DISCUSSION

These recent scientific investigations of Mondrian’s patterns highlight several crucial misconceptions about Mondrian’s compositional strategies. According to the emerging picture of Mondrian’s work, the lines that form the visual scaffold of his paintings are not random. However, their positioning doesn’t follow the traditional rules of aesthetics, nor does it deliver any appeal beyond that achieved using random lines. The aesthetic order of Mondrian’s paintings appears to be a consequence of the presence of a scaffold and it’s associated colored rectangles, rather than any subtle arrangement of the scaffold itself. In other words, the appeal of Mondrian’s visual language isn’t affected by the way the individual ‘words’ are assembled! What, then, were his reasons for developing such strict ‘grammatical’ rules for his visual language?

Mondrian wrote extended essays devoted to his motivations, and these focussed on his search for an underlying structure of nature [Mondrian, 1957]. This is surprising because, initially, his patterns seem as far removed from nature as they possibly could be. They consist of primary colors and straight lines - elements that never occur in a pure form in the natural world. His patterns are remarkably simple when compared to nature's complexity. However, his essays reveal that he viewed nature's complexity with distaste, believing that people ultimately feel ill at ease in such an environment. He also believed that complexity was just one aspect of nature, its least pure aspect, and one that provides a highly distorted view of a higher natural reality. This reality, he argued, "appears under a veil" - an order never directly glimpsed, that lies hidden by nature's more obvious erratic side. He believed that any glimpse through this "veil" would reveal the ultimate harmony of the universe. Mondrian wanted to capture this elusive quality of nature in his paintings.

Despite the differences in their chosen visual languages, both Pollock and Mondrian aimed to capture the underlying structure of the natural world on canvas. Declaring "I am nature," Pollock focused on expressing nature's complexity. Remarkably, he painted fractal patterns 25 years before scientists discovered that nature's complexity is built from fractals. Furthermore, based on the fractal aesthetic qualities revealed in the perception experiments, current research is aimed at reducing people’s physiological stress by incorporating fractal art into the interior and exteriors of buildings [Taylor et al, 2003, Wise et al, 2003]. These scientific investigations enhance Pollock’s artistic standing in the history of Modern Art, with his work interpreted as a direct expression of nature’s complexity. Now that science has caught up with Pollock, how should we view Mondrian's alternative view of nature?

The recent investigations of Mondrian's patterns indicate that peoples' aesthetic judgments of his visual language are insensitive to the ways that his language is applied. It's tempting to conclude that Pollock succeeded in the quest for natural aesthetics and that Mondrian failed. However, this interpretation doesn't account for the enduring popularity of Mondrian's patterns. Perhaps he succeeded in glimpsing through nature's "veil" with an unmatched clarity and was able to move his lines around with a subtlety well beyond our current scientific understanding of nature? Just as art can benefit from scientific investigation, so too can science learn from the great artists.

## ACKNOWLEDGMENTS

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