Fractals: A Resonance between Art and Nature

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Physics and Psychology Reveal the Fractal Secrets of Jackson Pollock's Drip Paintings

The discovery of fractal patterns was an interesting advance in the understanding of nature [1, 2]. Since the 1970s many natural scenes have been shown to be composed of fractal patterns. Examples include coastlines, clouds, lightning, trees, rivers and mountains. Fractal patterns are referred to as a new geometry because they look nothing like the more traditional shapes such as triangles and squares known within mathematics as Euclidean geometry. Whereas these shapes are composed of smooth lines, fractals are built from patterns that recur at finer and finer magnifications, generating shapes of immense complexity. Even the most common of nature's fractal objects, such as the tree shown in Figure 1, contrast sharply with the simplicity of artificially constructed objects such as buildings. But do people find such complexity visually appealing? In particular, given people's continuous visual exposure to nature's fractals, do we possess a fundamental appreciation of these patterns – an affinity independent of conscious deliberation?

The study of human aesthetic judgement of fractal patterns constitutes a relatively new research field within perception psychology. Only recently has research started to quantify people's visual preferences for (or against) fractal content. A useful starting point in assessing people's ability to recognize and create visual patterns is to examine the methods used by artists to generate aesthetically pleasing images on their canvases. More specifically, in terms of exploring an intrinsic appreciation of certain patterns, it seems appropriate to examine the Surrealists and their desire to paint images which are free of conscious consideration. Originating in Paris during the 1920s, the Surrealists developed their painting techniques more than fifty years ahead of the scientific discovery of nature's underlying fractal quality. Yet, remarkably, our recent research shows that fractals could have served as the foundation for Surrealist art and, in particular, the drip paintings of their artistic offspring, the American abstract painter Jackson Pollock.

The Surrealists' approach to painting deviated radically from the care and precision traditionally associated with artistic techniques. The Surrealists believed that premeditated, conscious actions hindered the liberation of *pure* imagery from deep within the mind [3]. They thought that the key to releasing this imag-

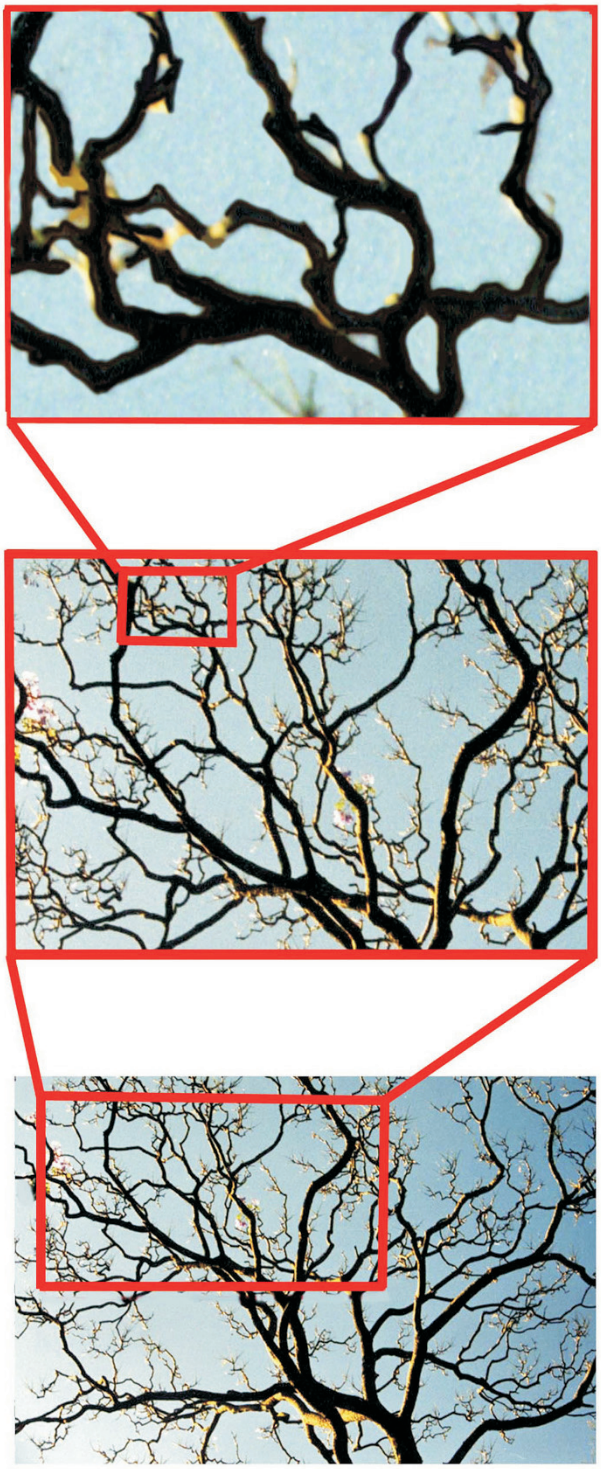

Fig. 1. Trees are an example of a natural fractal object. Although the patterns observed at different magnifications don't repeat exactly, analysis shows them to have the same statistical qualities (photograph by R.P. Taylor)

Fig. 2. A photograph of peeling wall paint. As a demonstration of *free association*, a picture of a person (*left*) and a bird (*right*) have been drawn based on images perceived within the peeling paint (photograph by R.P. Taylor)

ery lay in the exploitation of chance happenings. By staring at random patterns, such as those produced by a spilled bottle of ink, a chance arrangement of patterns might trigger the imagination and cause an image to emerge in the artist's mind. Adopting the Surrealist terminology, the random patterns were said to serve as a *springboard for free association*. The artist would then draw over the top of this springboard pattern, building a picture based on this initial perceived image. Interestingly, Leonardo da Vinci had already suggested a similar approach back in 1500 in his *Treatise On Painting*: "… a new inventive kind of looking consists in this, that you look at a wall which is marked with all kinds of stains. If you have to invent a situation, you can see things in it that look like various landscapes. Through confused and vague things the spirit wakes to new inventions." The technique is demonstrated in Figure Two, where we have drawn pictures of a person and a bird within the patterns of peeling wall paint. Whereas da Vinci's approach was passive – he simply used the springboards in his surrounding environment – the Surrealists actively created their own springboards by generating what they regarded as random patterns.

André Masson threw handfuls of sand over a canvas covered with glue. On tilting the canvas, sand fell off in some regions but not others. He then painted a human figure based on his perceptions of the springboard pattern of sand. Oscar Dominguez invented a technique labeled as *decalcomania*, where paint was spread on a sheet of paper, another sheet was pressed down lightly on top and then was lifted off before the paint had dried. He described the resulting pattern as "unequalled in its power of suggestion." Similarly, Joan Miró spread diluted paint across a canvas using a sponge in a random manner to encourage a chance emergence of a pattern. In 1925, Max Ernst introduced his *frottage* technique, where the springboard was created by randomly placing sheets of paper on the surface of an old wooden floor and taking rubbings with black lead. Ernst regarded this as a major breakthrough, remarking, "in gazing intently at the drawings thus obtained I was surprised by the sudden intensification of my visionary capacities". By the 1940s, Ernst had moved on to a new technique where paint was dripped onto a horizontal canvas from a leaking can swung randomly through the air on a piece of string. He moved to New York and stimulated a new generation of artists who later were to become known as the Abstract Expressionists. The most famous of these was Jackson Pollock, who, similar to Ernst, dripped paint from a can onto large horizontal canvases. Acknowledging the strong influence of the Surrealists, Pollock noted, "I am particularly impressed with their concept of the source of art being the unconscious." During Pollock's artistic peak of 1940s–1950s, however, art critics were generally unsympathetic to his achievements, describing his work as "mere unorganized explosions of random energy, and therefore meaningless." [4]

Whereas the Surrealists and their artistic offspring, the Abstract Expressionists, used these random patterns to trigger imagery for their artistic creations, the psychologists of the same era used similar patterns in the hope of assessing people's mental and emotional disorders. The most famous examples of this are the ink blot psychology tests introduced by Hermann Rorschach [5]. Rorschach's technique was inspired by a popular children's game known as blotto, where the players were asked to identify images within the patterns created by ink blots. Rorschach developed this simple concept into his Form Detection Tests, where the blot patterns were thought to act as springboards for free association and the images perceived by the observer were interpreted as direct projections of the unconscious mind. Rorschach died in 1922 having devoted just four years to his ink blot tests. However, during the 1940s and 1950s, the *Rorschach*, as it became known, became the test of choice in clinical psychology for assessment of mental disorders. While the use of these patterns for mental assessment is now only of historical interest, the ink blots clearly evoke meaningful images (Figure 3).

A recent perception study of free association has triggered renewed interest in the fundamental characteristics of ink blot patterns [6]. Bernice Rogowitz and Richard Voss investigated people's responses to fractal patterns. To do this they quantified the fractal patterns' visual character using a parameter called the fractal dimension, *D*. This parameter describes how the patterns occurring at different magnifications combine to build the resulting fractal pattern. As the name fractal dimension suggests, this building process determines the dimension of the fractal pattern. For Euclidean shapes, dimension is a simple concept and is de-

Fig. 3. Ink blot patterns created by R.P. Taylor using the technique employed by Rorschach when generating his ten original patterns

scribed by familiar integer values – for a smooth line (containing no fractal structure) D has a value of 1, whilst for a completely filled area (again containing no fractal structure) its value is 2. However, the repeating structure of a fractal pattern causes the line to begin to occupy area. D then lies between 1 and 2 and, as the complexity and richness of the repeating structure increases, its value moves closer to 2. Figure 4 demonstrates how a fractal pattern's D value has a profound effect on its visual appearance. For fractals described by a low D value close to one (left), 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 two the repeating patterns build a shape full of intricate, detailed structure (right).

The research by Rogowitz and Voss indicates that people perceive imaginary objects (such as human figures, faces, animals etc.) in fractal patterns characterized by low D values [6]. For fractal patterns with increasingly high D values this perception falls off markedly. This result caused Rogowitz and Voss to speculate that the ink blots used to induce projective imagery in psychology tests of the 1920s were fractal patterns described by low D values. Indeed, their subsequent

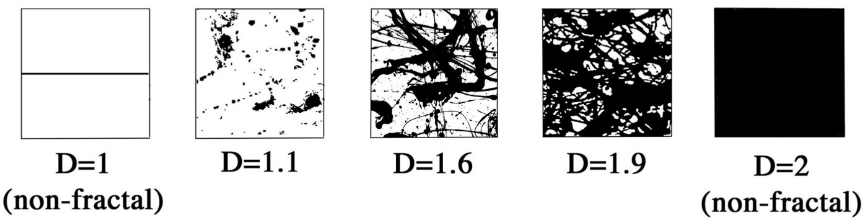

Fig. 4. A comparison of patterns with different D values: 1 (*left*), 1.1, 1.6, 1.9 and 2 (*right*)

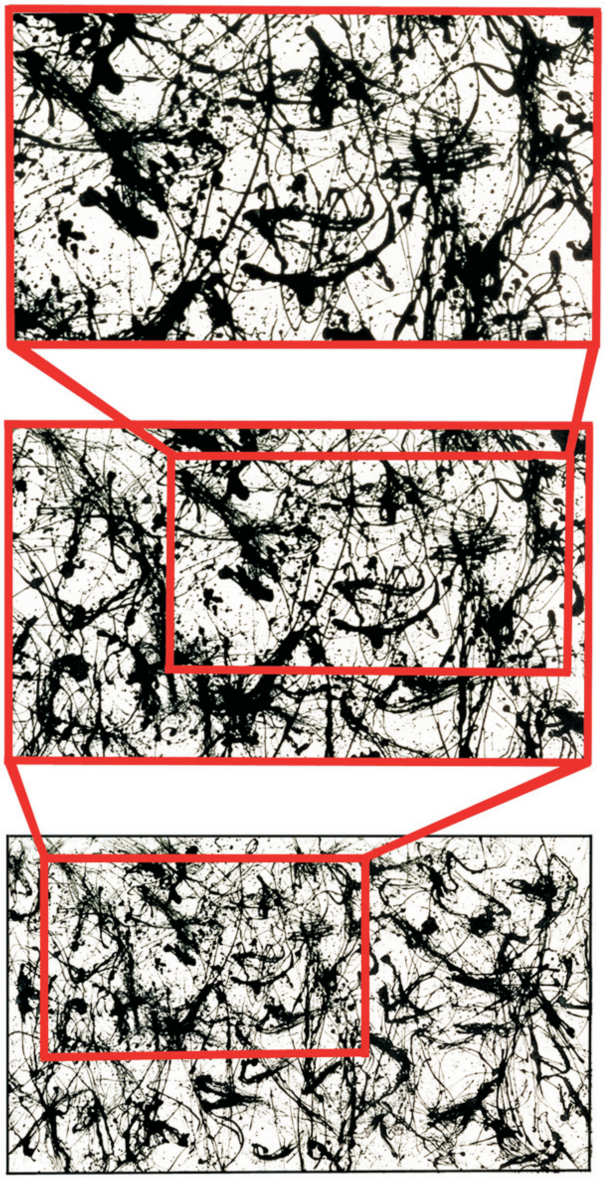

Fig. 5. Pollock's *Number 32,1950* reveals patterns at different magnifications. The fractal content of Pollock's dripped paintings has been confirmed by pattern analysis techniques. *Number 32, 1950* (enamel on canvas, 269 by 457.5cm) was painted by Pollock in 1950 (Kunstsammlung Norrhein-Westfalen, Düsseldorf)

preliminary analysis indicated that ink blots were fractal with a *D* value close to 1.25. Perhaps, then, the springboard patterns produced by the Surrealists, and later by the Abstract Expressionists, were also fractal? The repeating quality of Jackson Pollock's dripped paintings at different magnifications (shown in Figure 5) supports this speculation and our recent analysis of his work confirms their fractal content [7].

During his *classic* period of 1950, Pollock was filmed whilst painting. This serves as a remarkable visual record of how he used his perfected drip technique to build his fractal patterns. Our analysis of this film reveals that he differed from his Surrealist forerunners in one crucial respect. After 20 seconds of the dripping process, Pollock had established a fractal pattern with a low *D* value [2]. The Surrealists (and clinical psychologists) would have stopped at this initial stage and then used the pattern as a springboard for free association. For example, Max Ernst stopped dripping paint at the equivalent stage of his painting process and stared at the springboard layer in the hope of perceiving an image within the swirls of dripped paint. Then, based on this perception, Ernst drew a picture on top of the springboard layer. For the Surrealists, this drawing process was often so heavy that it obscured the underlying springboard layer, making a fractal analysis of this layer difficult. In contrast to this Surrealist technique, Pollock didn't stop dripping paint once the low *D* fractal springboard pattern had been established. Instead, he continued to drip paint for a period lasting up to six months. Depositing layer upon layer, he gradually built a highly dense fractal pattern. As a result, the *D* value of his paintings rose gradually as they neared completion, starting in the range of 1.3 to 1.5 for the initial springboard layer and reaching a final value as high as 1.9 [2].

When combined with the findings of Rogowitz and Voss, this time-sequence analysis provides an answer to one of the more controversial issues surrounding Pollocks drip work. Over the last 50 years there has been a persistent theory that speculates that Pollock painted illustrations of objects during the early stages of the painting's evolution and then deliberately obscured them with subsequent layers of paint [8]. In reality, the low *D* values evident during the early stages of the painting process simply caused the observer to perceive objects in the dripped patterns (even though they were not there) and these perceptions were then suppressed (making the objects apparently disappear) as *D* rose to the high value which characterized the complete pattern ([2].

Pollock's desire to paint fractal patterns is not surprising. Our initial perception studies revealed that over ninety percent of 120 participants found fractal imagery to be more visually appealing than non-fractal imagery [9, 10]. However, it is clear from our film analysis that Pollock's painting process was geared to more than simply generating a fractal pattern – if this were the case he could have stopped after twenty seconds, having established his fractal springboard pattern. Instead he invested a further six months fine-tuning his pattern to produce a fractal painting described by a high *D* value. Furthermore, his ability to paint fractal patterns with such high *D* values represented the culmination of almost ten years work during which he steadily perfected his drip process. When he first started to drip paint in 1943, he didn't build beyond the initial springboard layer. Inheriting the Surrealist technique, he used the low *D* fractal patterns to evoke images and then named his paintings after these images (*Eyes in the Heat* and *Water Birds* are example titles). In contrast, many of his paintings from his classic period of 1950 to 1952 were simply numbered or left untitled, presumably because the high *D* values of these fractal patterns no longer evoked any images. So why would Pollock invest so much effort in creating fractal patterns with such high *D* values? Perhaps he found such patterns to be aesthetically pleasing?

Fig. 6. Clouds form fractal patterns which, according to our survey, are aesthetically pleasing (photograph by R.P. Taylor)

In 1995, Cliff Pickover used a computer to generate fractal patterns with different D values and found that people expressed a preference for fractal patterns with a high value of 1.8 [11], similar to Pollock's paintings. However, a subsequent survey by Deborah Aks and Julien Sprott also used a computer but with a different mathematical method for generating the fractals. This survey reported much lower preferred values of 1.3 [12]. Aks and Sprott noted that the preferred value of 1.3 revealed by their survey corresponds to fractals frequently found in natural environments (for example, clouds and coastlines have this value) and suggested that perhaps people's preference is actually *set* at 1.3 through a continuous visual exposure to nature's patterns. However, the discrepancy between the two surveys seemed to suggest that there is not a universally preferred D value but that the aesthetic qualities of fractals instead depend specifically on how the fractals are generated. There are, in fact, three fundamentally different ways in which fractals can be generated – by nature's processes, by mathematics and by humans (as revealed by our analysis of Pollock's paintings). To determine if there are any *universal* aesthetic qualities of fractals, we therefore carried out a survey incorporating all three categories of fractal pattern and found that – irrespective of their origin – there was a distinct preference for D values in the range 1.3 to 1.5 [13]. Figure 6 shows an example that the survey revealed to be aesthetically pleasing – clouds with a D value of 1.3.

Perception studies of fractal patterns clearly have wide ranging implications for the types of environment which people find fundamentally pleasing. Our results indicate, for example, that architects should consider incorporating low D fractals into the interior and exterior surfaces of future building designs. Indeed, a dramatic demonstration of this occurred in November 2000 when the Guggenheim Museum unveiled plans for a new $ 800M building to house its modern art collection in New York [13]. Composed of swirling layers of curved surfaces, the 45 story structure is designed by the architect Frank Gehry to be cloud-like and is expected to radically re-shape Manhattan's waterfront (see the paper of Di Cristina in this volume, page ■). Although Gehry's building proposal for the Guggenheim Museum is designed to mimic the general form of clouds, it is clear that the completed building will not strictly be fractal. To build a structure described by a *D* value of 1.3 would require many layers of repeating patterns. Although this is no great challenge for nature, such complexity is beyond current building techniques. In fact, both Gehry and New York's former major, Rudolph Giuliani, readily admit that no shovel will be turned for at least 5 years and that the plans will have to evolve between now and then. However, it will be fascinating to see if people's fundamental appreciation of fractal clouds will inspire New Yorkers to embrace this revolutionary building design.

As for Jackson Pollock, he remains an artistic enigma. He could have stopped his painting process after less than a minute, having generated a pattern with a relatively low *D* value that people would have found visually appealing. Instead he spent six months depositing further layers, evolving the painting towards a higher *D* composition and apparently away from the aesthetic ideal. Should we conclude that Pollock wanted his work to be aesthetically challenging to the gallery audience? Perhaps Pollock's artistic achievement lies in his rebellion against our fundamental affinity for low *D* fractals. James Wise recently speculated that humans find low *D* fractal patterns aesthetically pleasing because these patterns make us feel safe in terms of our survival instincts. For example, it is easier to detect predators within natural scenery composed of sparse structure (low *D* fractals) than complex structure (high *D* fractals) [14]. Alternatively, as discussed above, Aks and Sprott argue that our preference for low *D* patterns occurs simply because these patterns are more abundant in nature and that we acquire (either implicitly during our lifetimes or through evolution) an appreciation for what we are familiar with [12]. Which ever of these two theories we apply to Pollock's paintings, the low *D* patterns painted in his earlier years should have a more calming effect than his later *classic* drip paintings. What was motivating Pollock to paint high *D* fractals? It is possible that he regarded the restful experience of a low *D* pattern as being 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 plan to investigate this intriguing possibility by performing eye-tracking experiments on Pollock's paintings, which will assess the way people visually assimilate fractal patterns with different *D* values.

In light of Pollock's interest in Surrealist techniques – the art movement most closely associated with operations of the mind – it is fitting that the discipline providing recent insights into the visual significance of Pollock's work is that of psychology. The impact of Pollock's work on psychology research extends beyond our perception studies of his fractal patterns. Whereas perception psychologists are interested in the visual impact of Pollock's completed patterns, behavioral psychologists are intrigued by his painting process and how a human was able to generate fractal patterns. Recently, we described Pollock's style as Fractal Expressionism to distinguish it from computer-generated fractal art [15]. Fractal Expressionism indicates an ability to generate and manipulate fractal patterns *directly*. Furthermore, our analysis shows that the fractal quality of Pollock's paintings was established within a remarkably quick time frame – within less than one minute. How could someone paint such intricate and complex fractal patterns, so precisely, so quickly and do so 25 years ahead of the scientific discovery of fractals?

A common interpretation of Pollock's painting process focuses on the Surrealist technique called *psychic automatism* [3]. In this technique, artists painted rapidly and spontaneously, with such speed that conscious intervention was thought to be suppressed. In this way, their gestures were regarded as being *steered* by the unconscious. Critics have since questioned whether psychic automatism can be achieved in reality. In 1959, Rudolph Arnheim rejected the concept as "romantic" and proposed that the relaxation of conscious control would simply lead to nothing more than a confused and patternless disorder [16]. However, as we have seen, the patterns pouring onto Pollock's canvas weren't disorganized – they were fractal. Why would this be? Questions such as this have attracted the attention of medical researchers who investigate the basic rhythms of the human body. Ary Goldberger and his research team study the dynamics of human processes that operate independently of conscious control, including heart beats and stride length during walking [17]. They conclude that strict periodicity in such processes is a signature of a pathological condition and that a healthy behavior instead reveals fractal variations around this periodicity. This suggests that, in surrendering conscious control, the Surrealist method of automatism might tune into the basic fractal rhythms of the human body and that Pollock applied this to his drip technique. Future research will be needed to further explore the link between the aesthetic qualities of fractal patterns and the human ability to paint them.

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