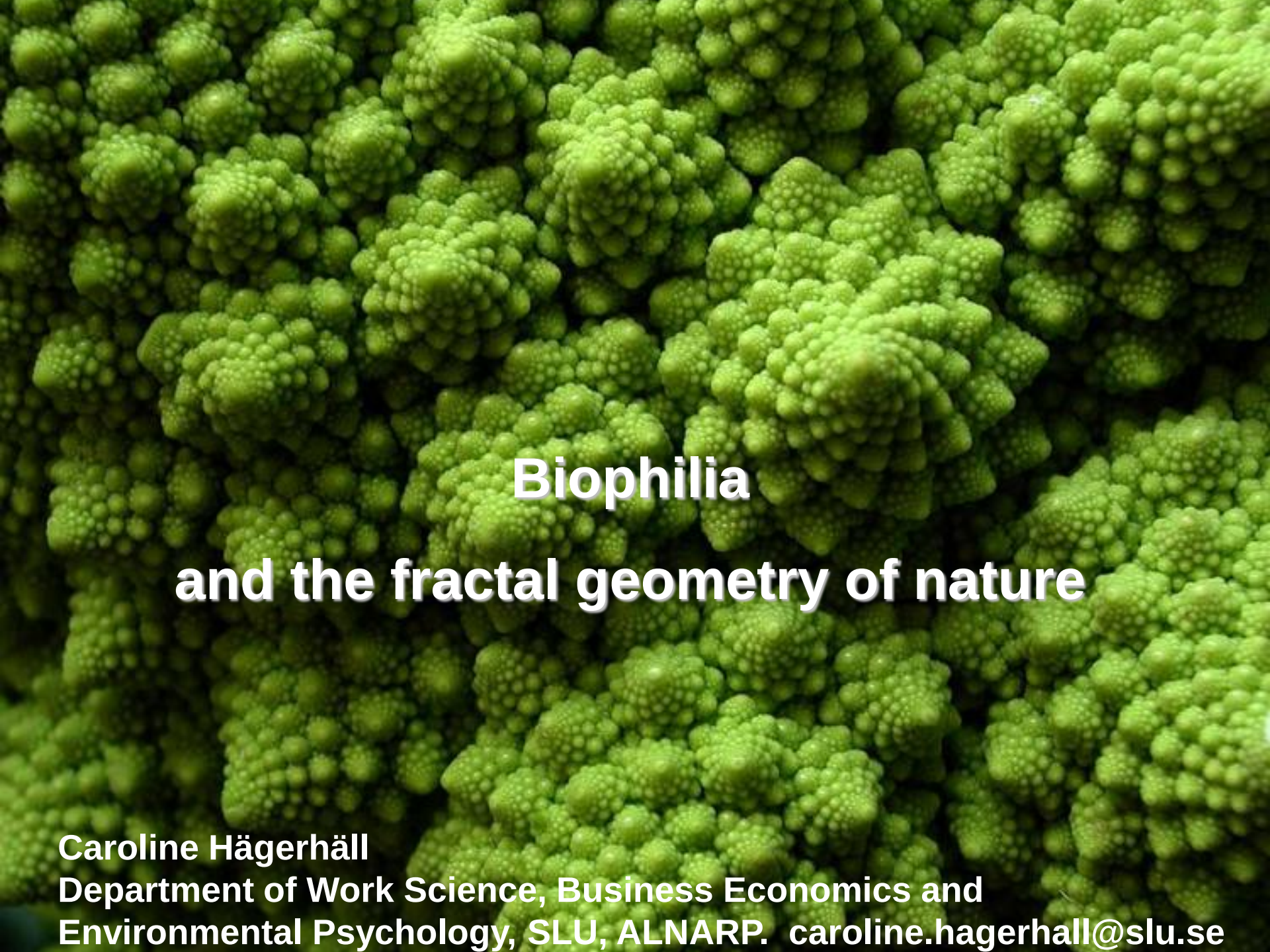




Biophilia and the fractal geometry of nature

Caroline Hägerhäll

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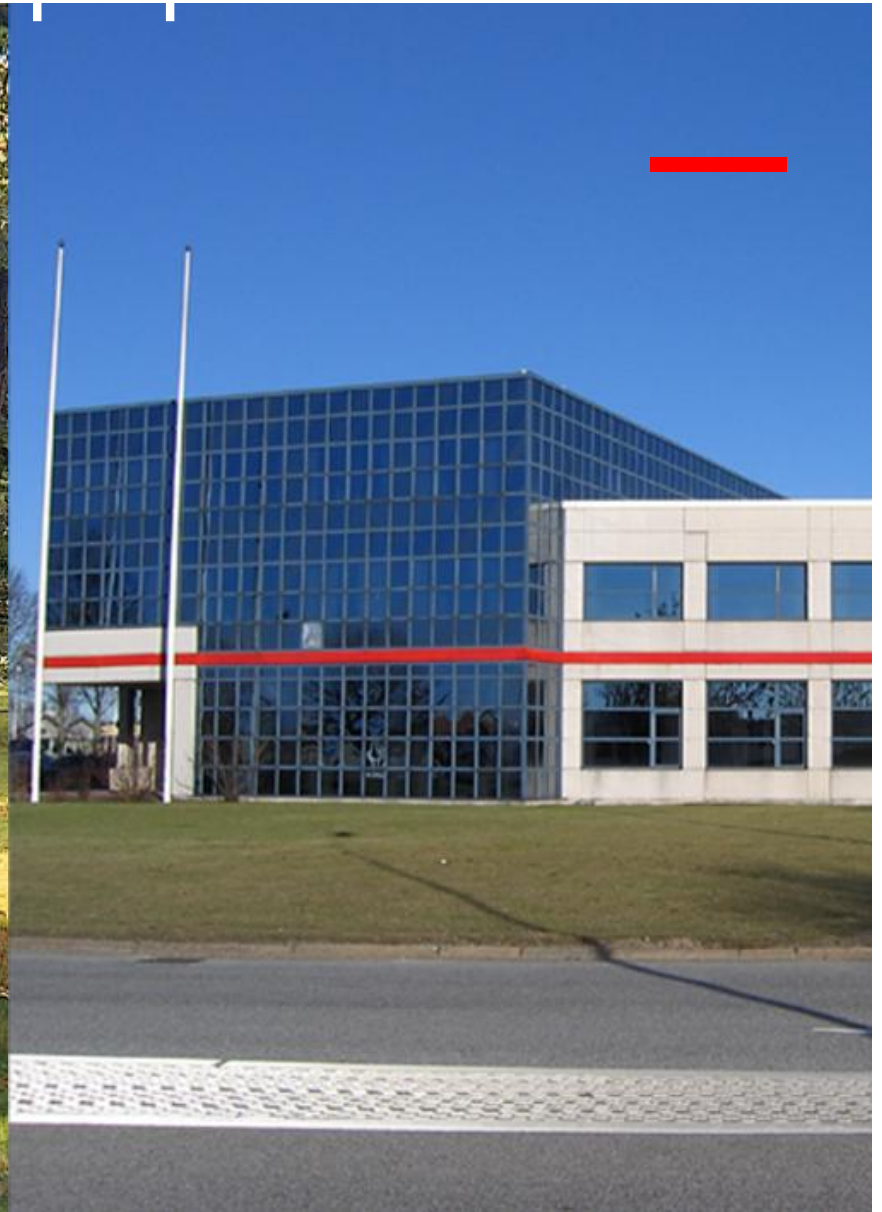
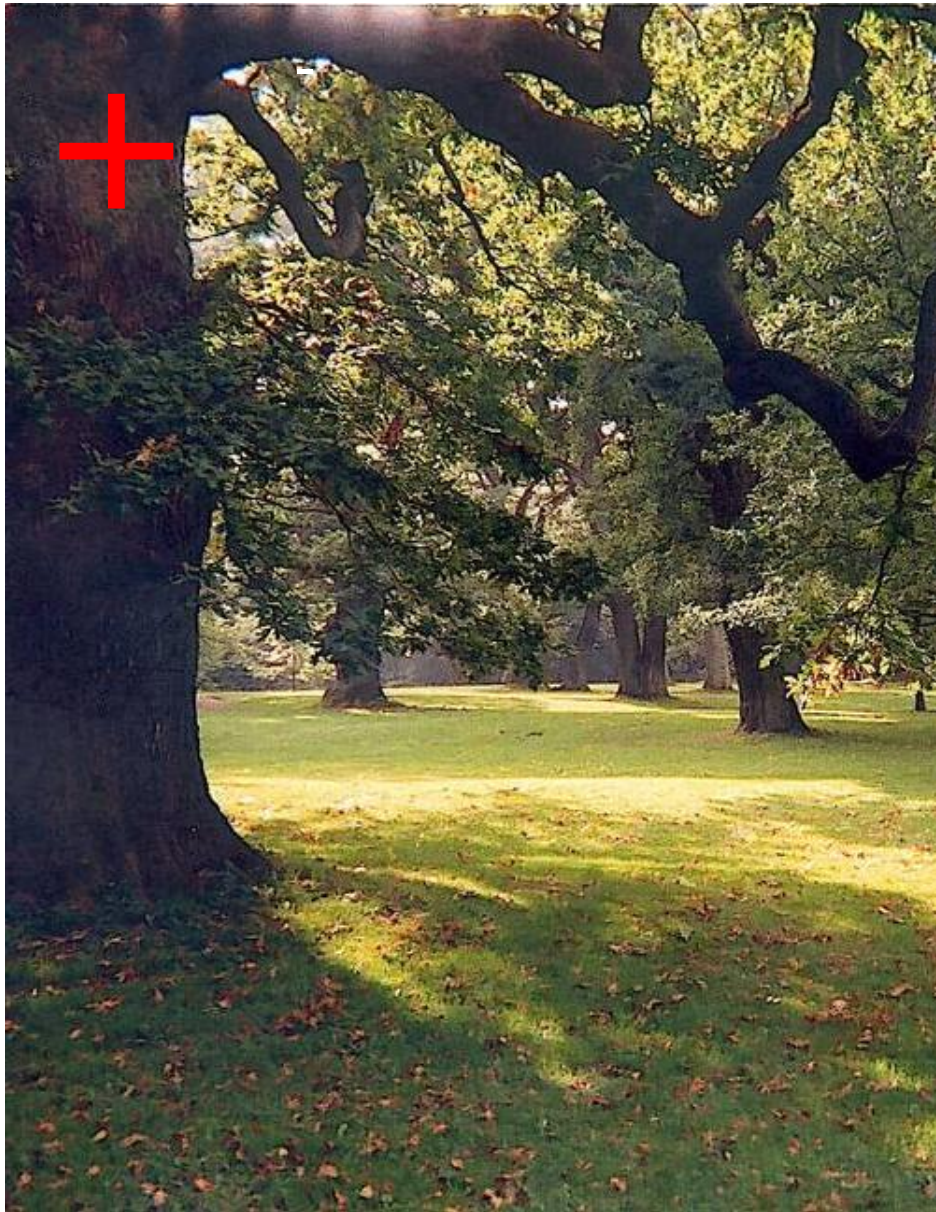
The consensus assumption

Similarities in response to natural scenes outweigh the differences across individuals , groups and cultures.

Evolution has lead to innate preferences for particular environments, particularly open expanses with clusters of trees



Savannah Theory (Orians 1980) Biophilia (Fromm 1964, Wilson 1984, Ulrich 1993)



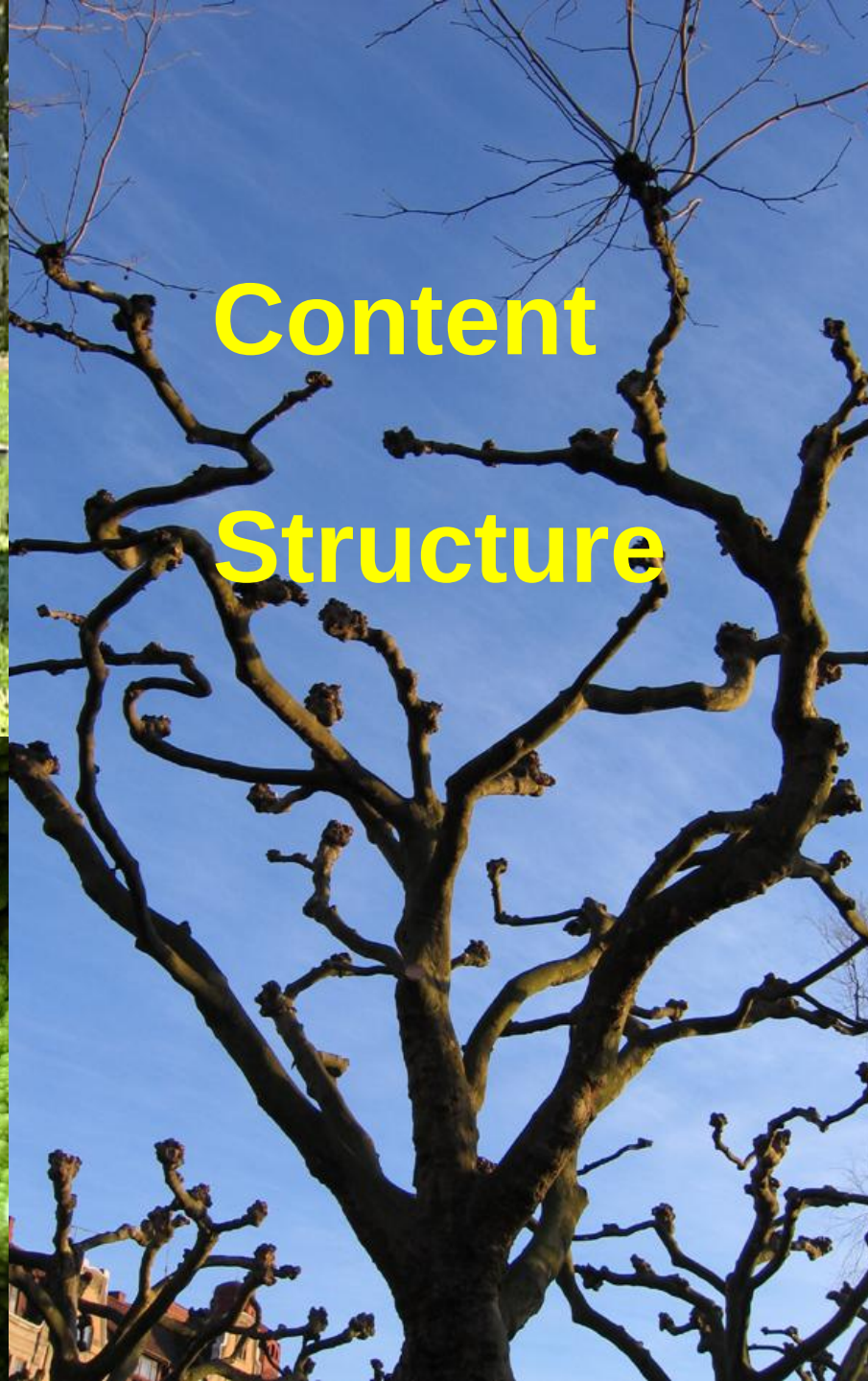




Kaplan & Kaplan preference matrix

- Human functioning is dependent on **how we process information**.
- Preference includes function.
- Everyone knows what they like...and that makes the rating an easy task.
- What are the basis for a preference judgment and what in the environment makes it meet those needs?

	Understanding	Exploration
Immediate	Coherence	Complexity
Inferred	Legibility	Mystery



Content
Structure



Preference – "Health"

"The nervous system seem to be structured in such a way that pleasure and pain tend to inhibit each other; thus the experience of pleasure tends to reduce or eliminate pain. "

"Because contact with pleasurable stimuli can control pain, it should be possible to confront uncertainty and confusion in environments that are experienced as pleasurable.

Further, the experience of pleasure should reduce the need for directed attention. "

"A preferred environment is thus more likely to be a restorative environment. And since nature plays such a powerful role in what is preferred, in general terms, there is a theoretical basis for expecting natural environments to be restorative."

(Kaplan and Kaplan , The Experience of Nature, 1989)

Attention Restoration Theory

Stephen Kaplan

Professor
Dept. of Psychology
University of Michigan
USA



Concentration requires the ability to suppress competing stimuli

This ability can be depleted and it can be restored

directed attention



"fascination"



effortless and with unlimited capacity



” Many of the fascinations afforded by the natural setting qualify as soft fascinations: clouds, sunsets, snow patterns, the motion of the leaves in the breeze- these readily hold the attention, but in an undramatic fashion.

Attending to these patterns is effortless, and **they leave ample opportunity for thinking about other things.** ”

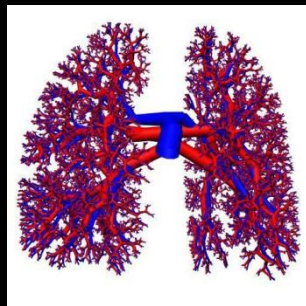
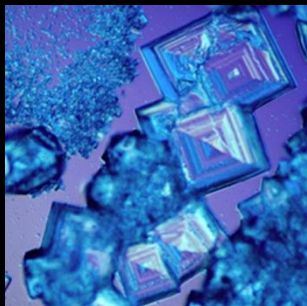
Kaplan, S. (1995) The restorative benefits of nature: Towards an integrative framework. *Journal of Environmental Psychology*, 15, 169-182.

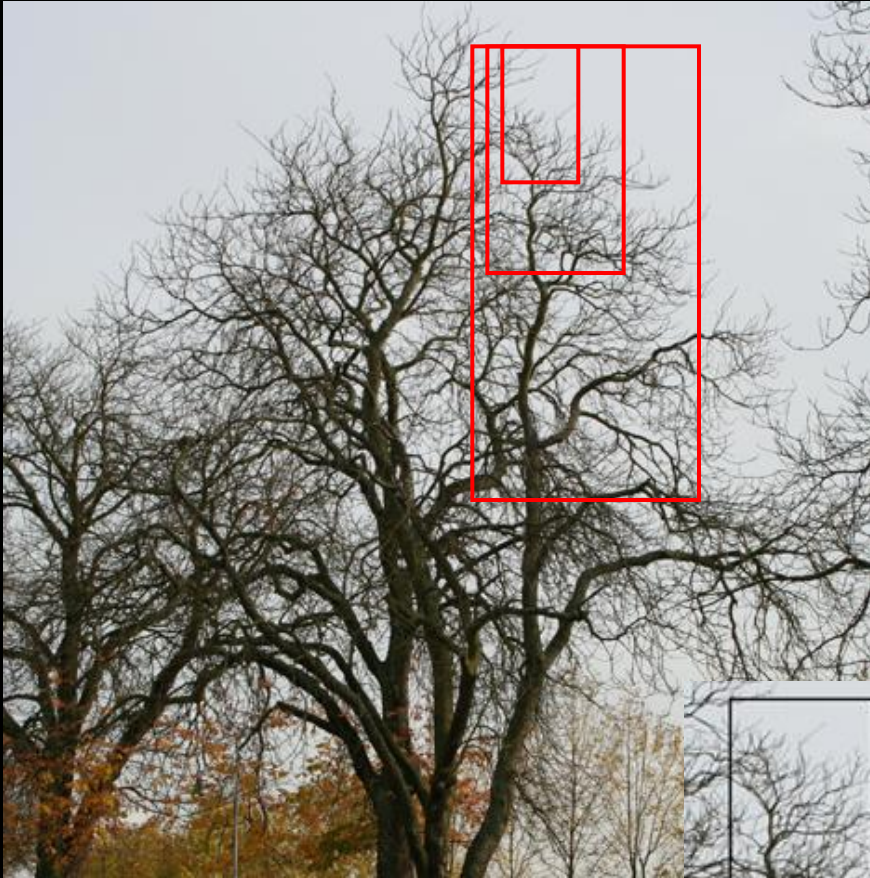






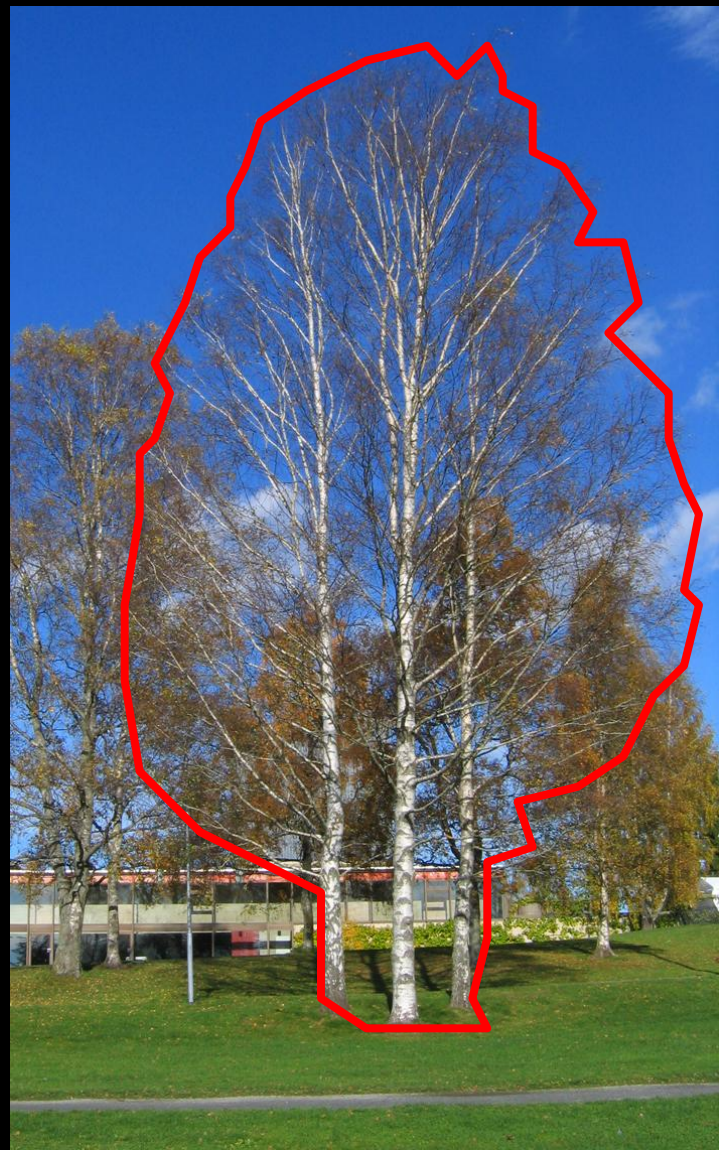
What is it in nature that makes attending to it fascinating and at the same time effortless?

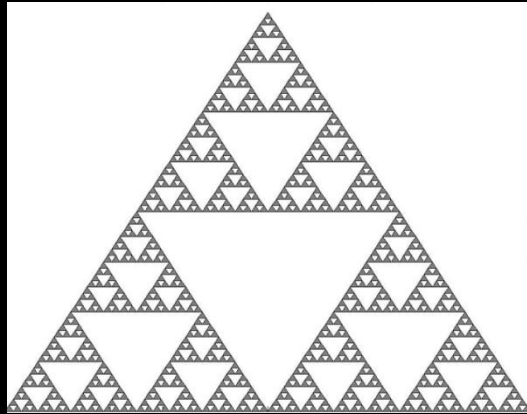
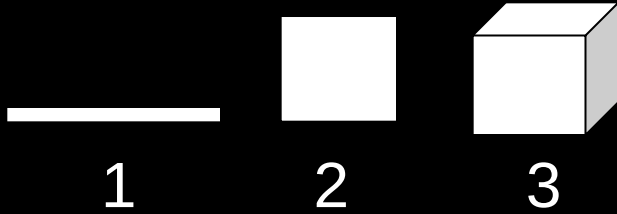




A fractal has the characteristic of being self-similar, i.e. the same pattern will appear again and again when a fractal object is viewed at increasingly fine magnifications.







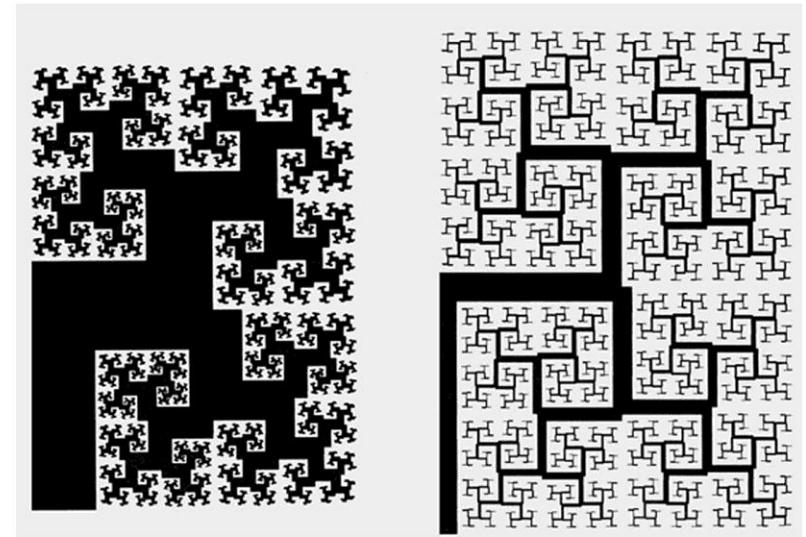
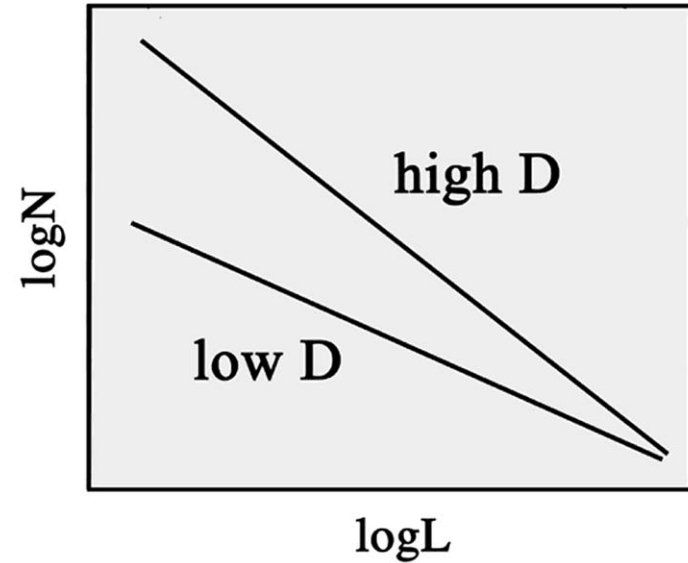
Sierpinski
gasket
 $D = 1.58$

Fractal dimension D

Repetition

+

Amount of detail



low D

high D

Natural phenomena and their fractal dimensions

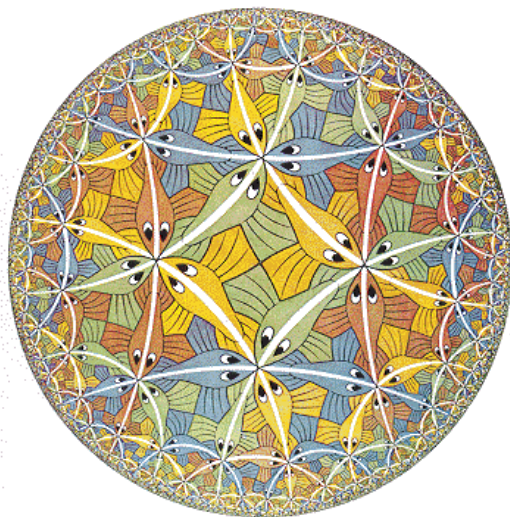
Phenomena	Fractal dimension	Source
Coastlines: South Africa, Australia,UK,Norway	1,05-1,25 1,52	Mandelbrot Feder
Wooded plants and trees	1,28-1,90	Morse et al.
Waves	1,3	Werner
Clouds	1,3-1,33	Lovejoy
Sea anemon	1,6	Burrough
Bacterial growth patterns	1,7	Matsushita et al.
Electric discharge	1,75	Niemyer et al.
Mineral patterns	1,78	Chopard et al.



Elliot waves

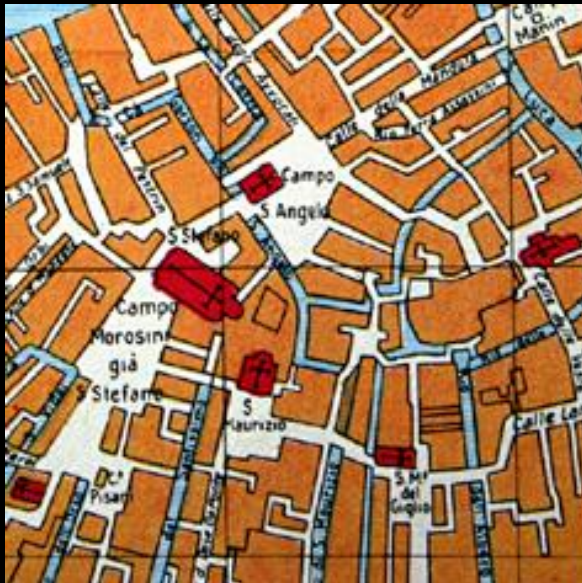
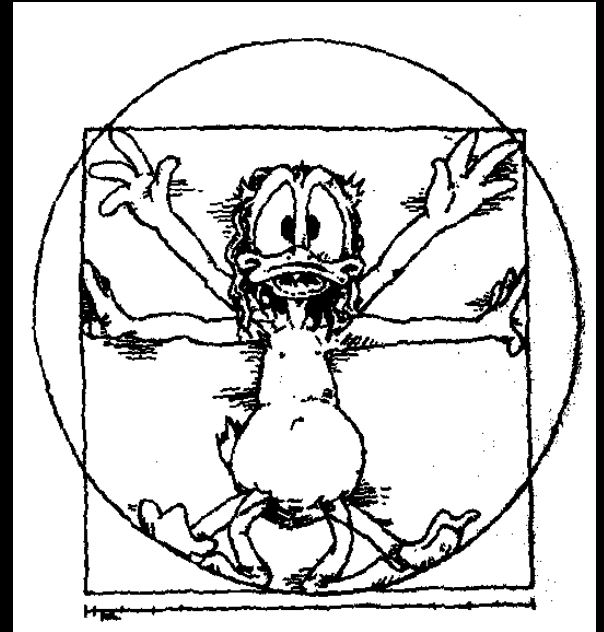
Pollock painting

M.C. Escher



Fractals :

- combines order and complexity
- a structural property
- found in human physiology
- and in art, architecture.....





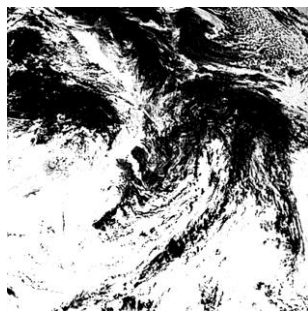
Can fractal properties help define general concepts like complexity and coherence?

Can fractal properties, like self similarity between scales, explain why attending to natural environments is supposedly more effortless, and allows one to direct attention inward thinking about other things?



Fractals and aesthetic experience

- Many speculations but few empirical studies
- Inconsistent results of preferred D value
- D 1.3-1.5 of particular importance for preference and restoration?



1.3

Natural



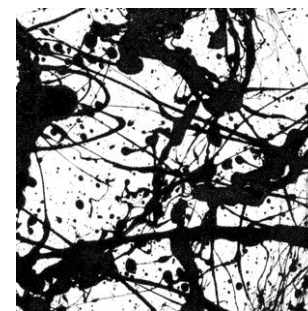
1.7



1.5

Jackson Pollock

1.7



1.3

Computer



1.7

Fractals with a dimension 1.3-1.5 were most preferred irrespective of origin (natural, human, artificial)

Taylor, R.P, Spehar, B., Wise, J.A., Clifford, C.W.G., Newell, B.R., Hagerhall, C.M., Purcell, T. & Martin, T.P. (2005). Perceptual and Physiological Responses to the Visual Complexity of Fractal Patterns. *Journal of Nonlinear Dynamics, Psychology, and Life Sciences*, Vol. 9, Iss. 1, January, pp. 89-114.

Visual preference as a function of D .
“forced choice” paired comparison

Consistent responses of preference for mid D over different shapes



$D=1.1$



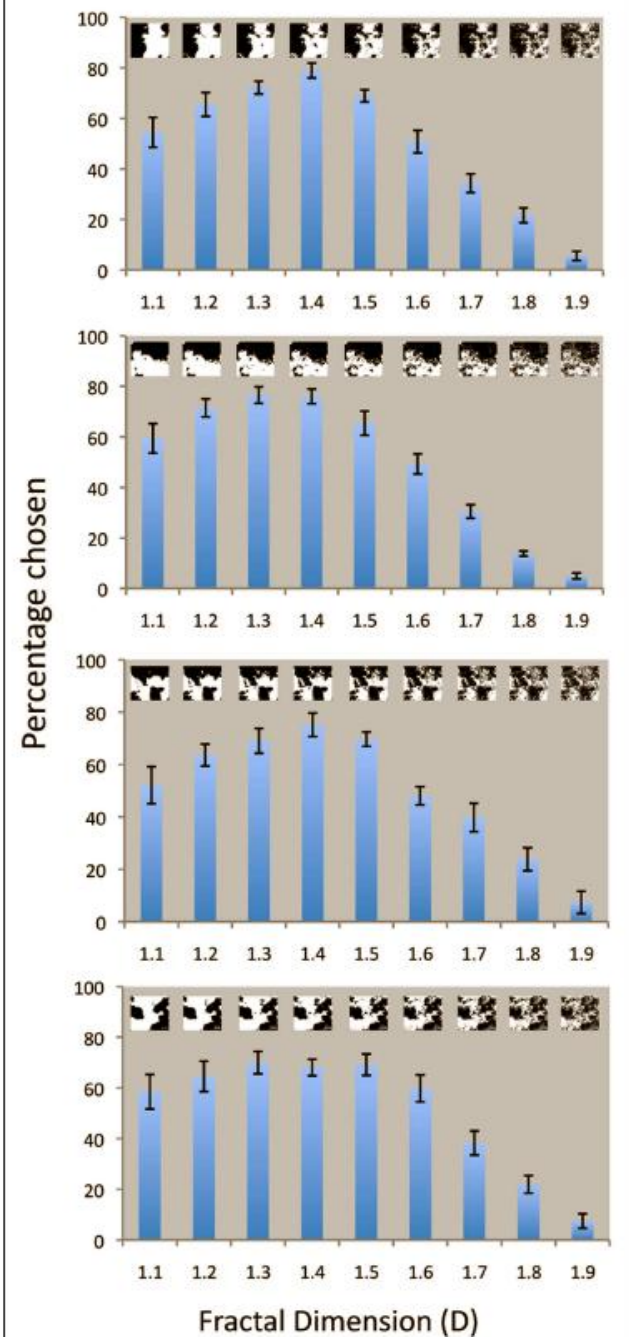
$D=1.3$

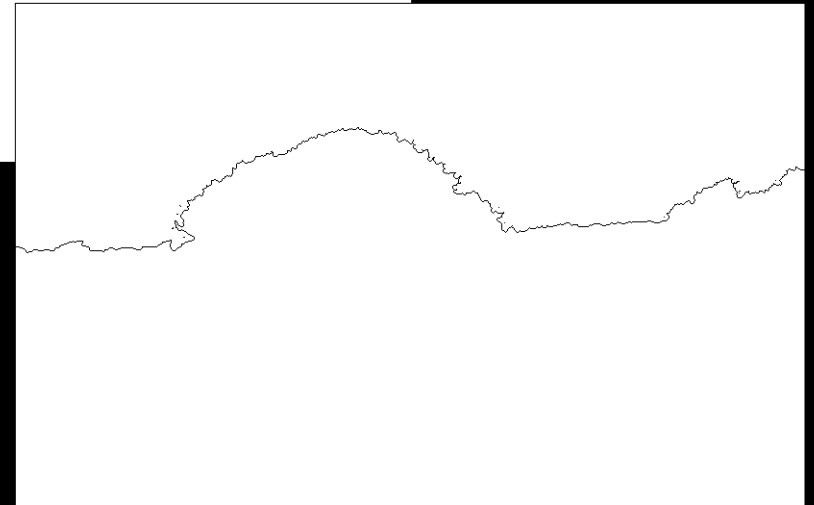


$D=1.7$

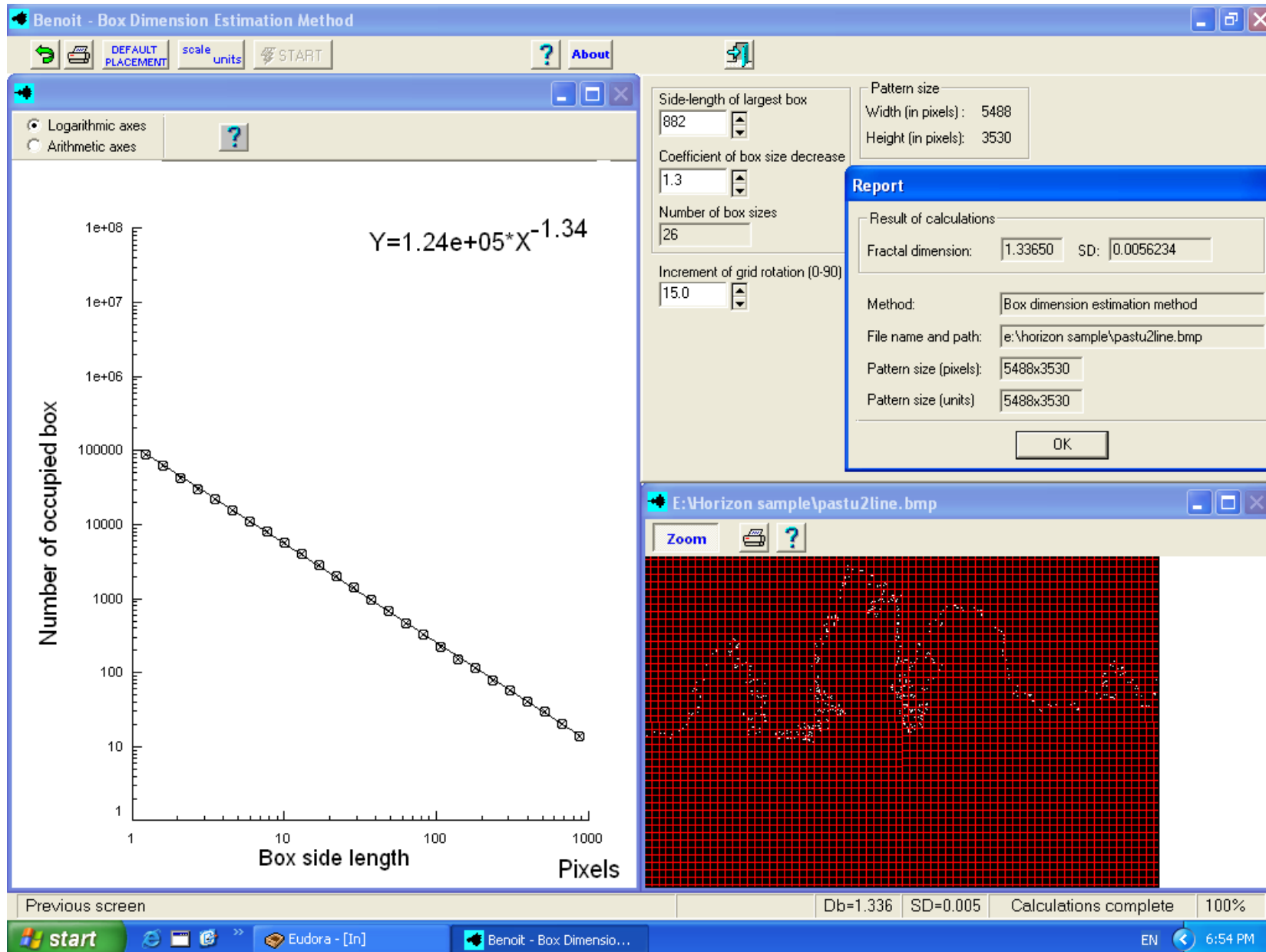


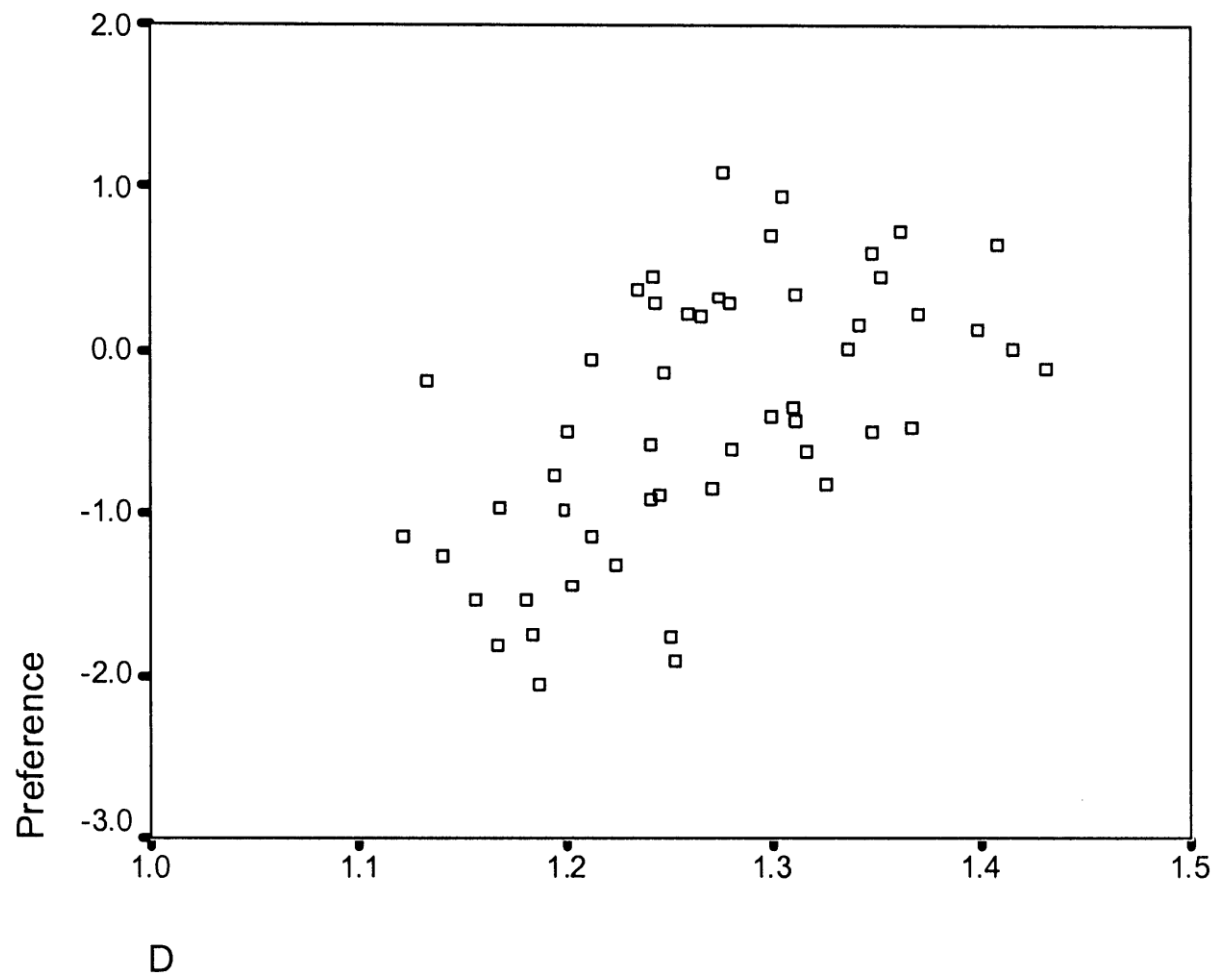
Taylor, R., Spehar, B., Van Donkelaar, P., Hagerhall, C.M (2011)
“Perceptual and physiological responses to Jackson Pollock’s
fractals”. *Frontiers in Human Neuroscience*. June 2011, Vol 5,
article 60.





Hagerhall, C. M., Purcell, T. & Taylor, R. (2004). Fractal Dimension of Landscape Silhouette Outlines as a Predictor of Landscape Preference. *Journal of Environmental Psychology*. 24, 247-255.

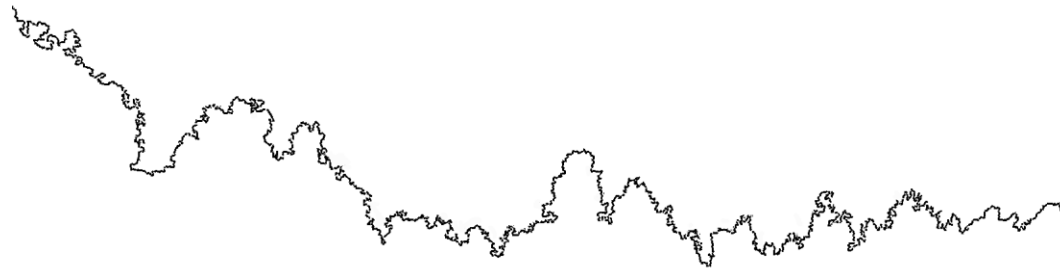




Hagerhall, C. M., Purcell, T. & Taylor, R. (2004). Fractal Dimension of Landscape Silhouette Outlines as a Predictor of Landscape Preference. *Journal of Environmental Psychology*. 24, 247-255.

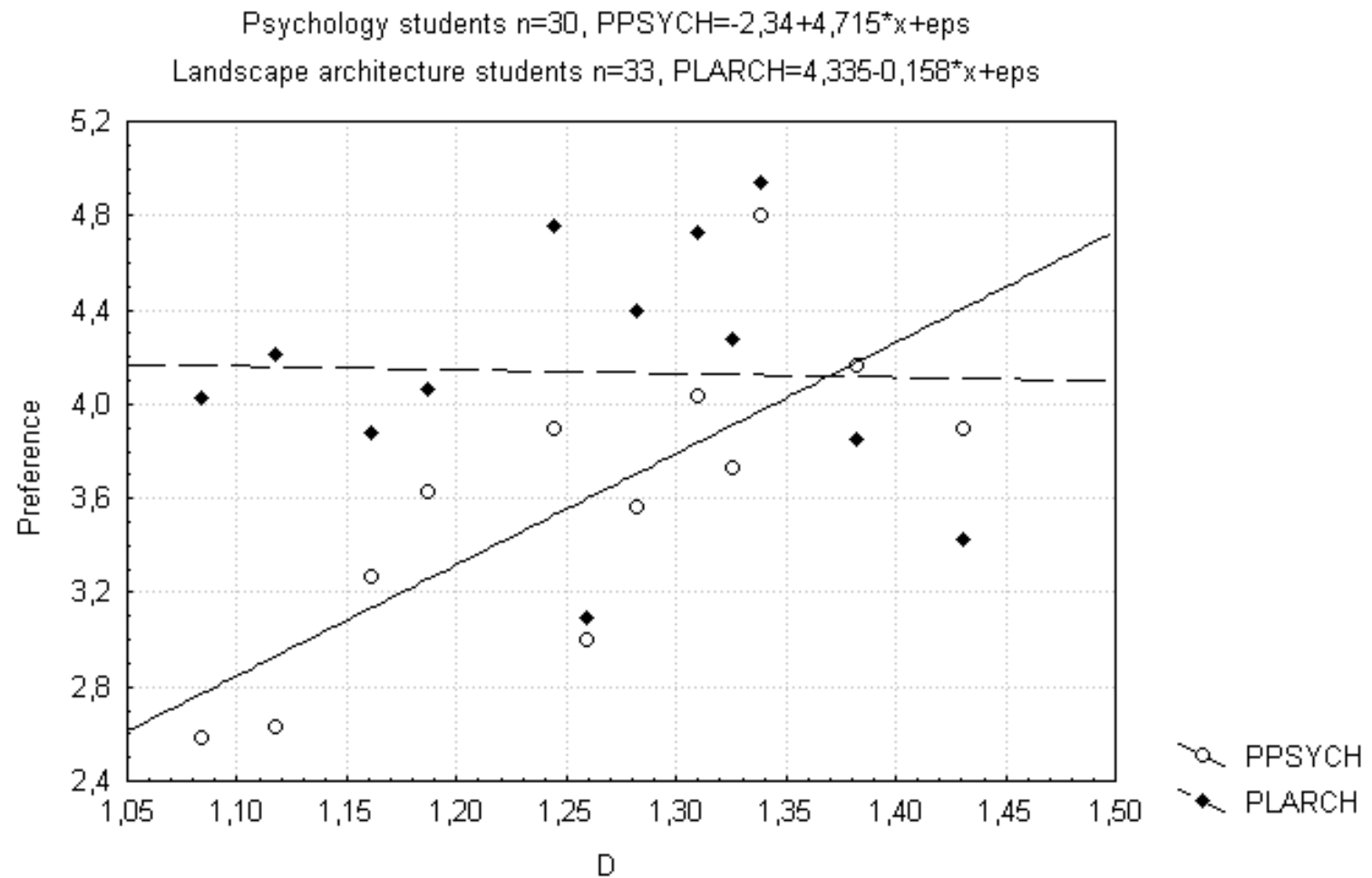


$D = 1.19$



$D = 1.31$

Hagerhall, C. M. (2005). Fractal Dimension as a Tool for Defining and Measuring Naturalness. In B. Martens and A. G. Keul (eds), *Designing Social Innovation - Planning, Building, Evaluating* (pp. 75-82). Cambridge, MA :Hogrefe & Huber.



Hagerhall, C.M. (2005). Fractal Dimension as a Tool for Defining and Measuring Naturalness. In B. Martens and A. G. Keul (eds), *Designing Social Innovation - Planning, Building, Evaluating*. Cambridge, MA :Hogrefe & Huber



Physiological processes in humans have fractal properties, for instance the heart rhythm

Can fractal patterns be used to affect physiological processes?

Pilot studies showed that fractal scenes with dimensions 1.3-1.5 seemed to reduce stress.



1.6



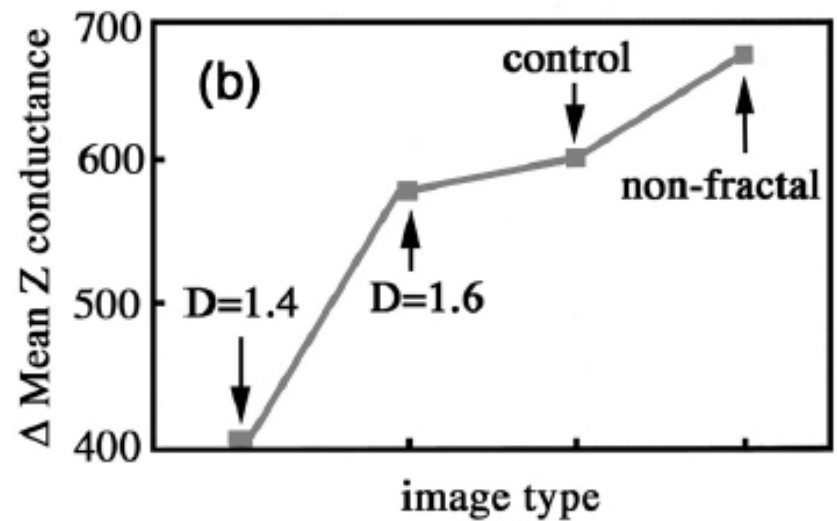
1.4



Non fractal

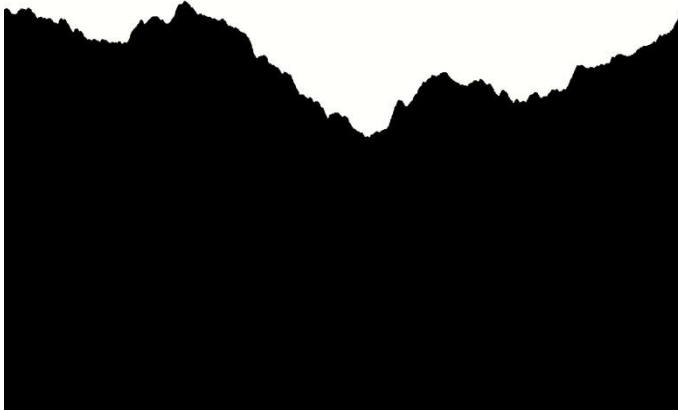
D calculated on the combination of the edge contours of all the objects in the image.

Control image: a white panel

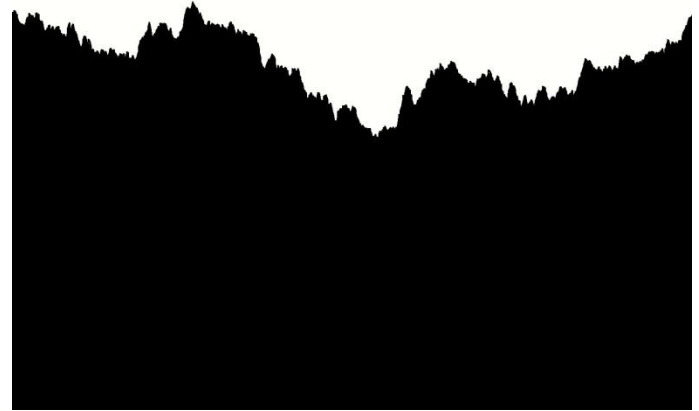




D 1.14



D 1.32



D 1.51

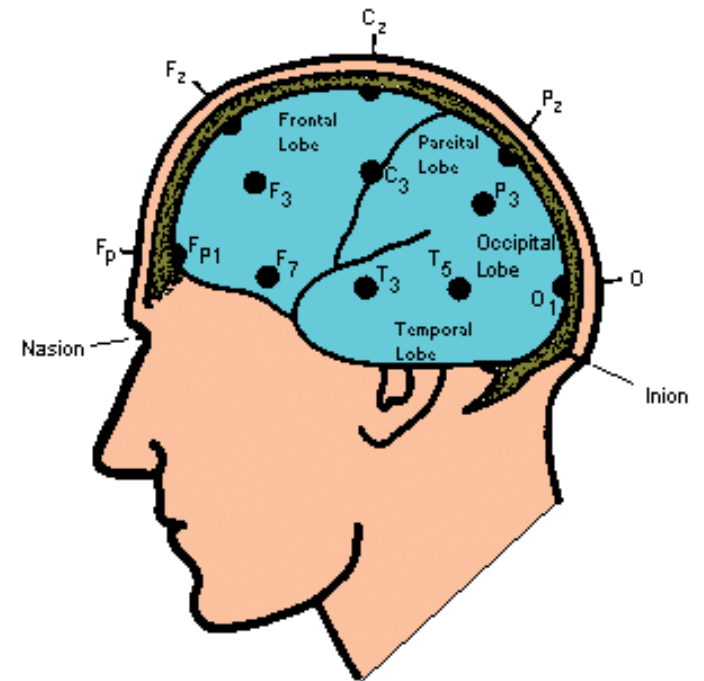


D 1.70

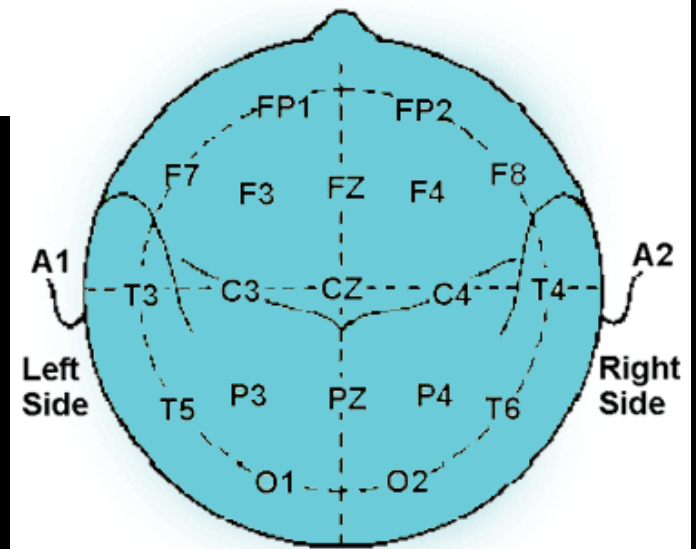


Hagerhall, C.M., Laike, T., Taylor, R., Küller, M. Küller, R., Martin, T. (2008) "Investigations of human EEG response to viewing fractal patterns". *Perception*, 37, 10, 1488-1494.

Supported by Formas, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning.



Front



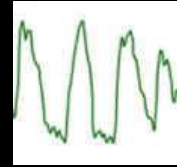
Back

Elektroencefalografi, EEG

EEG, electric activity from the cortex



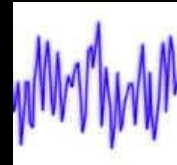
Delta 0 - 4 Hz Deep sleep, drowsiness



Theta 4 - 7 Hz Memory functions, emotions



Alfa 8 - 13 Hz Activation, relaxed with
attention turned inwards



Beta 14 - 30 Hz Intense mental activity,
thinking, problem solving,
active attention directed outwards

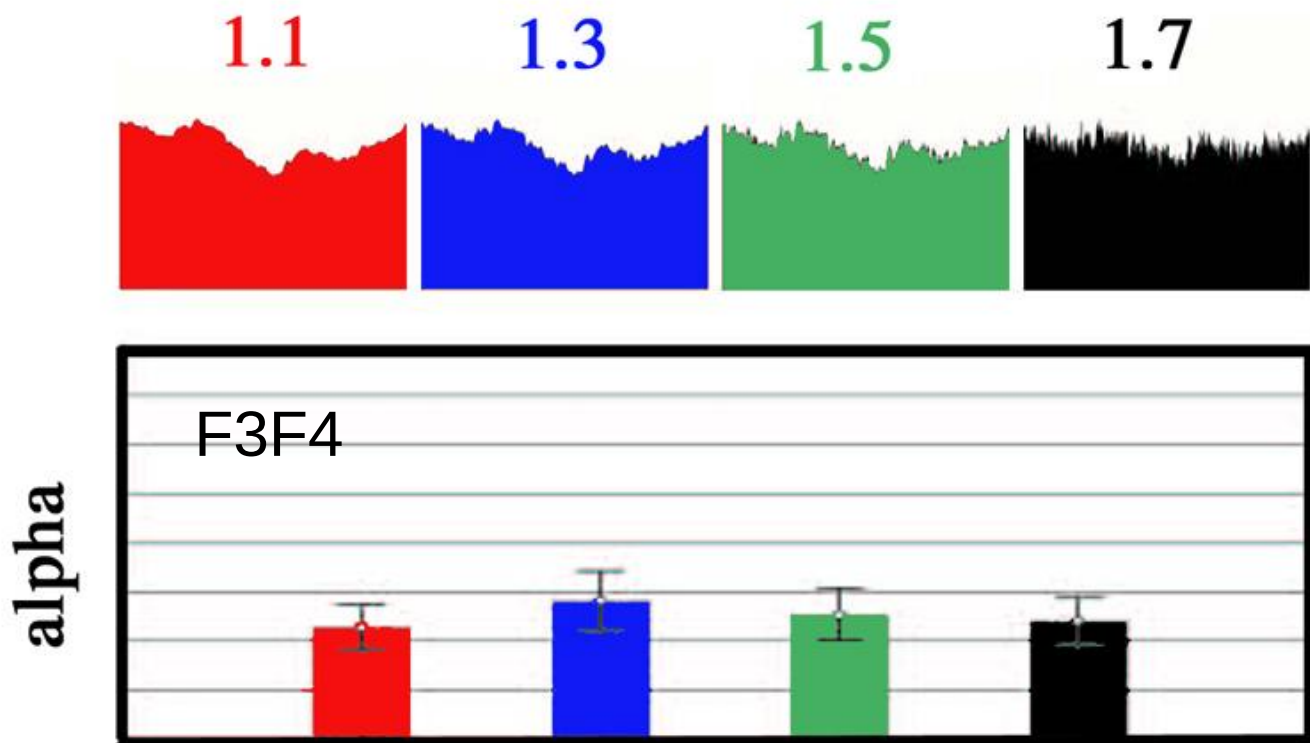


Hypothesis: more "fascination" = more alfa

Increase in alpha indicates

- cortical idling (Adrian and Matthews 1934)
- reduced information processing (Pfurtscheller 2001)
- active inhibition of non-task relevant areas or processes (Cooper, Croft et al. 2003; Klimesch, Sauseng et al. 2007),
- Suppression of competing information (Ward 2003).
- alpha is higher when the attention is directed inward on mental imagery than when attention is directed towards external information-intake tasks (Cooper, Croft et al. 2003; Ward 2003).
- meditation (Aftanas and Golocheikine 2001)

<i>Item</i>	F3- Ref	F4- Ref	P3- Ref	P4- Ref	T5- Ref	T6- Ref
<i>Delta Power</i> (mV ²)	3,42	6,40	0,88	1,18	2,03	2,04
<i>Theta Power</i> (mV ²)	1,45	1,27	1,35	1,45	2,75	3,08
<i>Alpha Power</i> (mV ²)	7,31	7,42	21,13	24,86	33,71	60,45
<i>Beta Power</i> (mV ²)	2,67	5,50	3,58	2,84	4,74	4,71
<i>Total Power</i> (mV ²)	171,8 4	307,2 5	212,4 5	358,9 1	486,8 2	535,8 2
<i>Mean Power</i> (mV ²)	0,33	0,60	0,41	0,70	0,95	1,04



$N = 32, m = 35,2$

$F_{1,29} = 6.38, p = 0.02$

Hagerhall, C.M., et al. (2008). *Perception*, 37, 10,1488-1494.

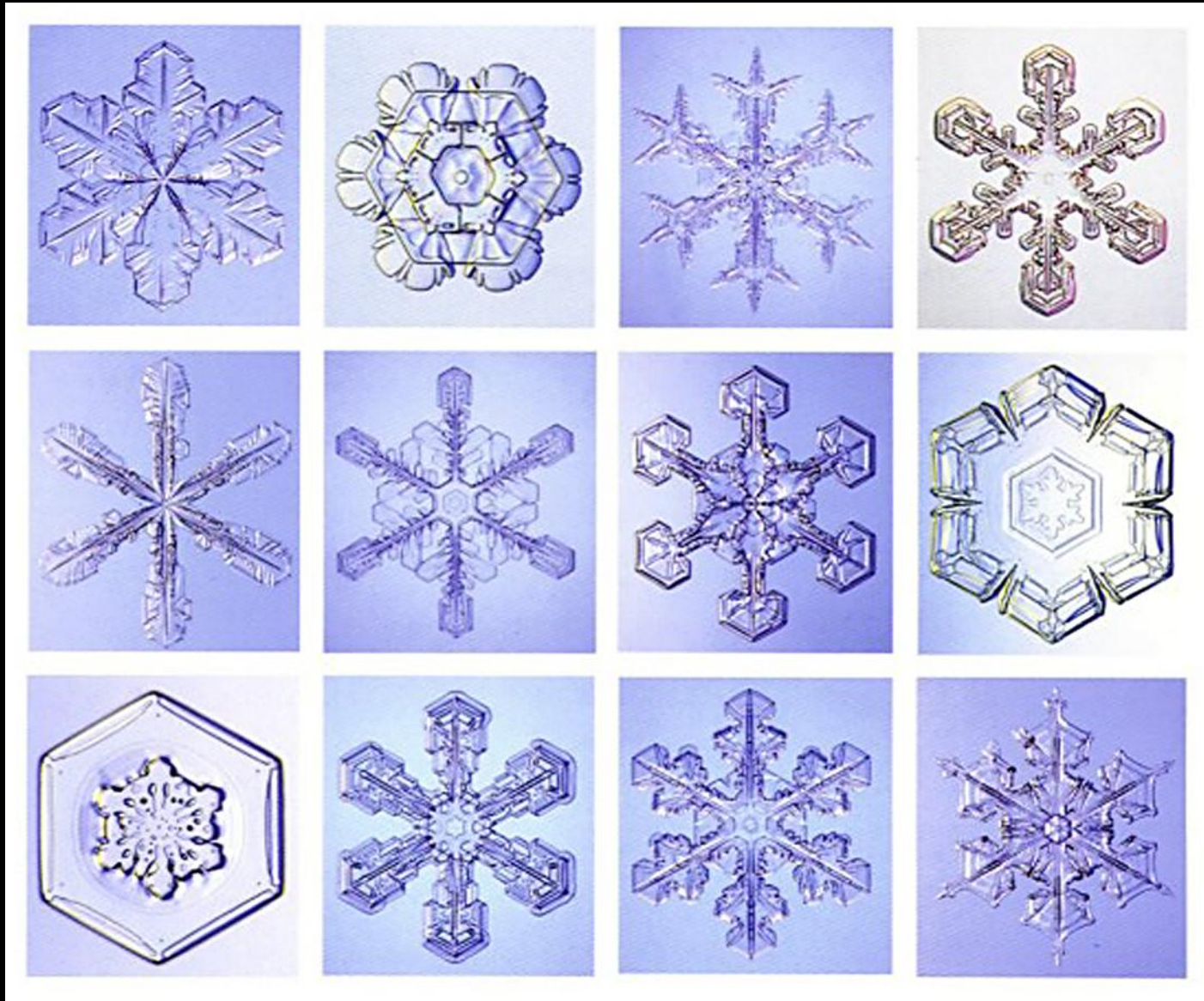


Conclusions

We have been able to show significant effects of the fractal dimension on psychophysiological responses, and this already with simple silhouette patterns. These results also point to dimensions around 1.3 being of particular importance.

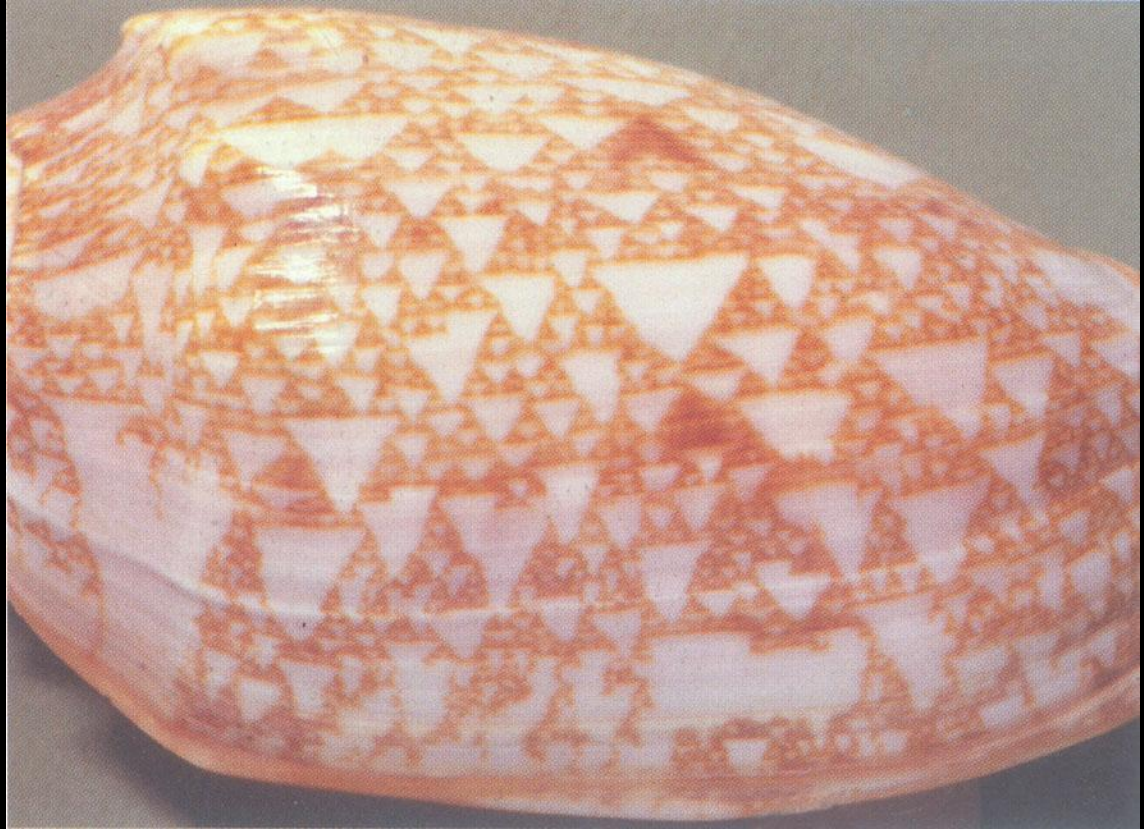
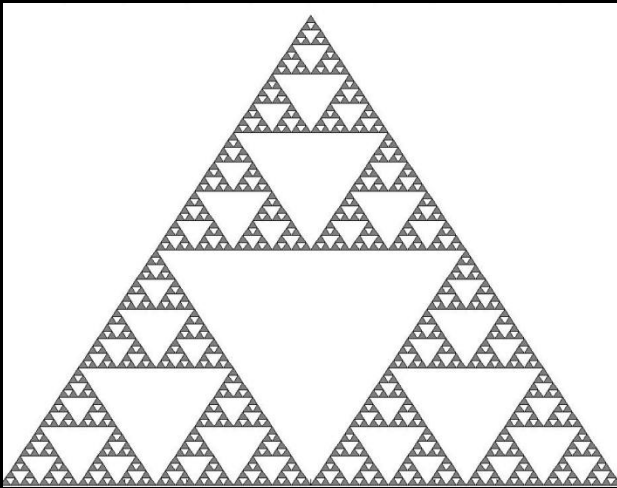
D1.32 had highest alpha frontally and at the same time highest beta in the parietal areas.

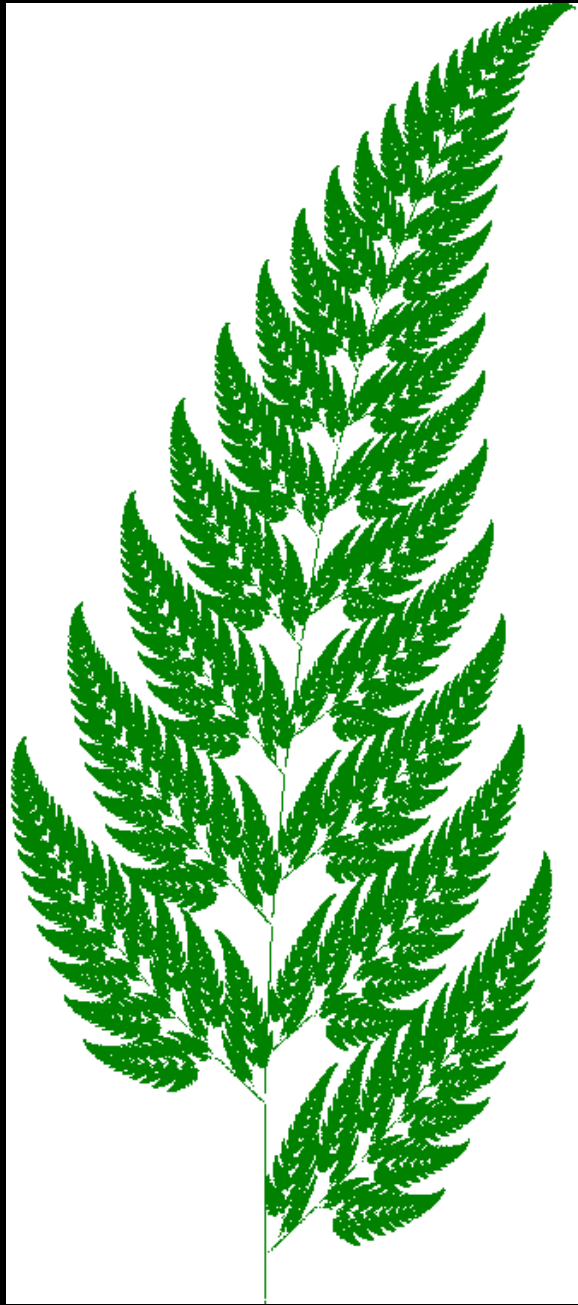
Simulations or real objects



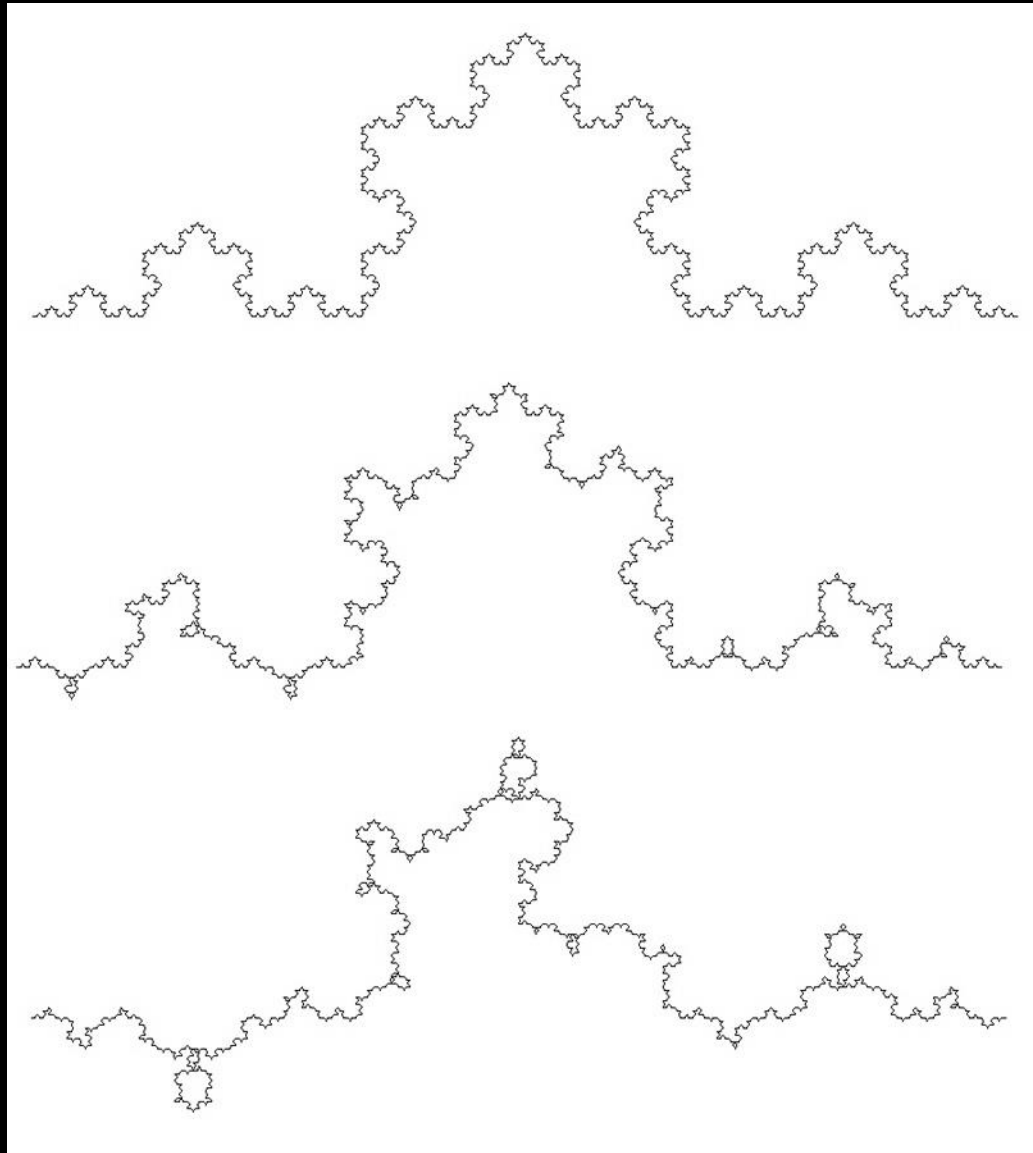
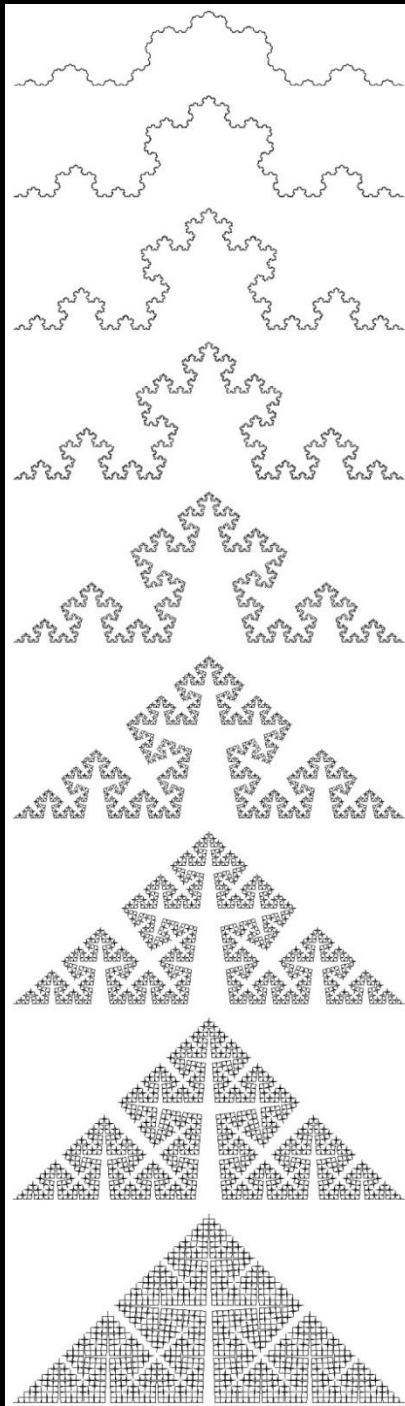
Exact and statistical self similarity

Sierpinski triangle
 $D = 1,58$

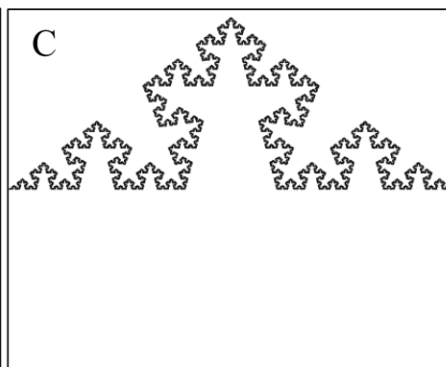
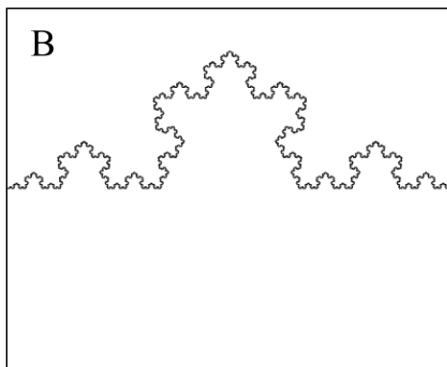
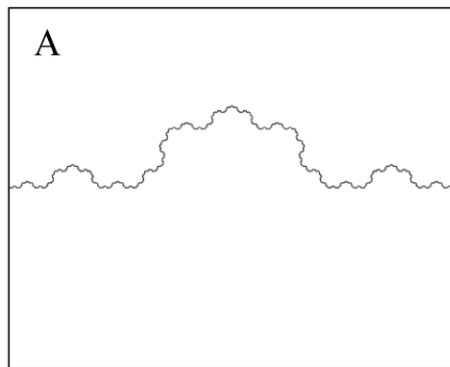




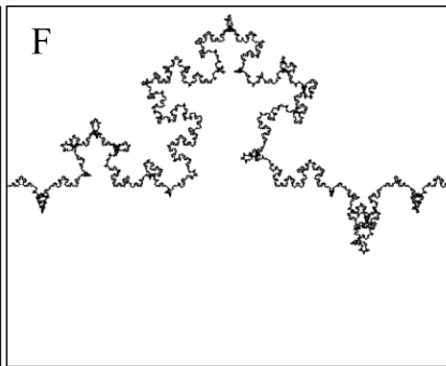
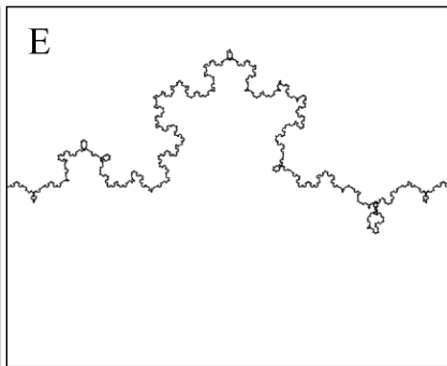
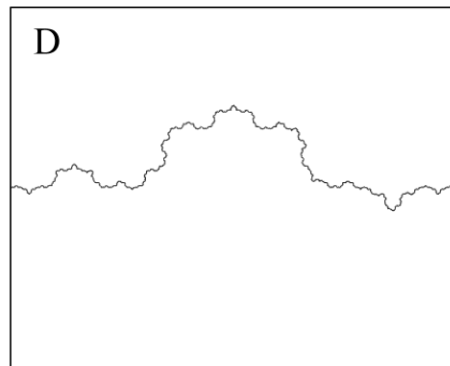
Koch curve, Helge von Koch (1904)



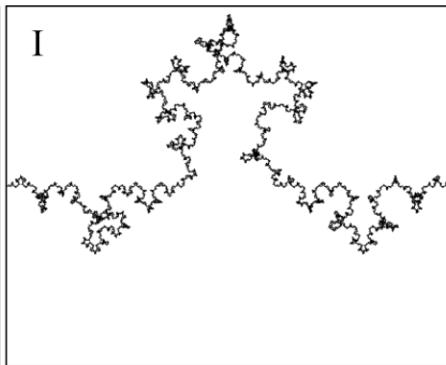
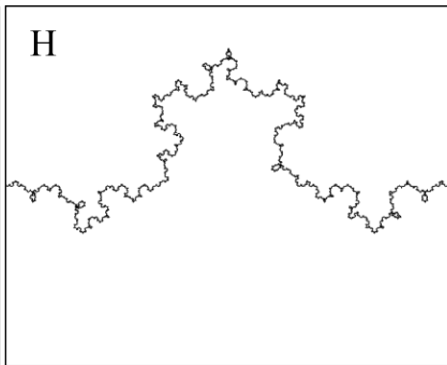
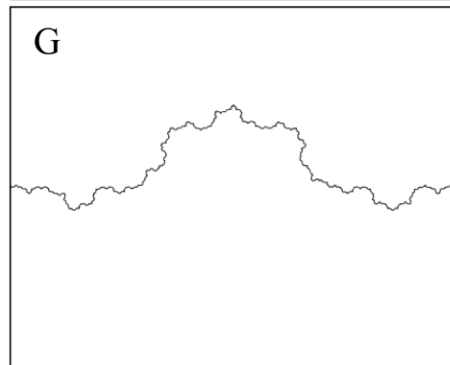
P .00



P .25



P .50



D 1.1

D 1.3

D 1.5

N = 35
m = 46,2

Both D and randomness, as well as interactions between them have effects on the EEG.

Alpha increase with randomness at all positions, i.e. alpha power increases as we gradually evolve from the exact fractal to the statistical fractal, which confirms our hypothesis that the natural form of the fractal is important for inducing alpha responses.

As in previous studies frontal Alpha was highest for mid D (1.3).

Higher alpha activity in left than right hemisphere in the frontal region, indicating a broader attention

Hagerhall et al , (submitted)

Conclusion

Systematic responses.

In line with hypotheses and previous findings.

Seems to be a fundamental basis for human reactions to fractal dimension and randomness in visual patterns that is worth to study further.

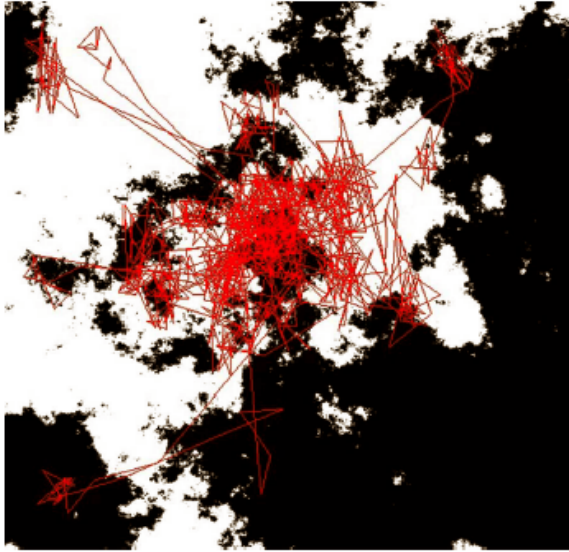


FIGURE 6 | An example of the computer-generated fractals (black and white) viewed by the subjects for the eye-tracking results shown in Table 2. The red lines are the eye trajectories.

Table 2 | A comparison of the D values of the fractal images being viewed, and the D values of the patterns traced out by the saccades.

D image	D saccade
1.1	1.5
1.2	1.5
1.3	1.5
1.4	1.6
1.5	1.5
1.6	1.6
1.7	1.5
1.8	1.5
1.9	1.5

Inherent search pattern set at $D = 1.5$, regardless of the D values of the fractal pattern being observed. It suggests that the eye's search mechanism follows an intrinsic mid-range D value when in search mode. The amount of space covered by fractal trajectories is bigger than for random trajectories, and a mid-range D value appears to be optimal for covering terrain efficiently.



“What happens when the eye is made to view a fractal pattern of $D = 1.5$? Will this trigger a “resonance” when the eye sees a fractal pattern that matches its own inherent characteristics? Could such a resonance lead to a peak in aesthetic appeal?”

Taylor, R., Spehar, B., Van Donkelaar, P., Hagerhall, C.M (2011)
“Perceptual and physiological responses to Jackson Pollock’s fractals”.
Frontiers in Human Neuroscience. June 2011, Vol 5, article 60.
http://www.frontiersin.org/Human_Neuroscience/archive/2011/Jun



Perceptual fluency/processing fluency.

Fluent processing – positive affect

Effortless processing – concept of fascination in ART

Natural scenes processed more fluently than urban
due to higher coherence,
which in turn could be due to fractal characteristics.

(Joye, Y. & Van den Berg, A., 2011, UFUG, 10, 261-268

Is love in our genes? A critical analysis of evolutionary assumptions
in restorative environments research)



Questions

Questions

Questions

Questions

Questions

Questions

Questions

Questions

Questions

Questions

Questions

Questions

Questions

Questions

Questions

Questions