Proceedings of the 11th International Congress on Empirical Aesthetics, Budapest, Aug 22-25, 1990, Budapest.

Fractal dimensionality and preference for synthetic random dot patterns.

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Experimental aesthetics has long tried to use Fechner's method of study "from below", by asking subjects to express preferences for synthetic geometric stimuli, and the method has been successfully applied to objects such as rectangles and triangles (see McManus, 1980). However such stimuli fail conspicuously to encapsulate the complexity and detail either of natural stimuli or of art objects. Attempts to study more complex objects have generally only been concerned with stimuli generated by purely random processes (such as the NxN black and white matrices generated by Dorfman and McKenna (1966), in which each cell has a 0.5 probability of being black or white). However such stimuli fail as adequate experimental stimuli in that pure mathematical randomness does not seem to be related to the true complexity of natural or artistic objects, even such paintings as the seemingly random Abstract Expressionist paintings of Jackson Pollock revealing themselves as being far more structured and more textured than do such random matrices. In this paper we describe the generation of complex black and white NxN matrices which are not entirely random, and hence contain structure and organisation, and hence show a greater similarity to natural and art objects.

In recent years there has been a massive surge of interest in fractal geometry (see Mandelbrot, 1977), which is capable of providing useful descriptions of such complex natural objects as coastlines, clouds and mountains, which have defied conventional analysis. Essentially fractal geometry considers objects such as coast-lines to have dimensions which are intermediate between the integers required by Euclidean topology. The line of a coast is therefore of higher dimension than a straight line (of dimension 1), but of lesser dimension than an area (of dimension 2), the fractal dimension becoming higher and higher as the line fills more and more of space, until eventually in such complex objects as the Peano curve the line fills two-dimensional space and achieves a dimension of 2. The important feature for present purposes is that dimensionality is a measure of complexity, objects of lesser dimensionality being more auto-correlated.

Voss and Clarke (1975) have shown that such fractal dimensions are a good description of the temporal patterns found in speech and music, and other studies (Gardner, 1978) have synthesised music of fractional dimension between 1 and 2, and shown that music is preferred if it has an intermediat dimensionality (1/f) between that of pure randomness ("white noise") and th very slowly changing structure of Brownian motion ("brown noise").

In this paper we describe how we have used a method of Fourie synthesis (Barnsley et al, 1988, p 90 et seq) to create black-white matrice that topologically are two-dimensional but have fractional geometri dimensions of varying degrees.

Method.

Subjects. 43 subjects (16 male, 27 female) took part in the experiment, mos of whom were undergraduates at University College London. Ages ranged fro 17 to 65 (mean = 22.7 years).

Stimuli. On each trial subjects were presented with a pair of NxN matrice which differed in their fractal dimension. Exactly 50% of the cells in eac matrix were black and 50% were white. A Fourier Synthesis method was use to create the stimuli in which an appropriate amplitude and phase spectru were created, and then an Inverse Fast Fourier Transform was used to creat the image corresponding to the spectrum. Specifically the amplitude spectru was created such that,

$$\log(\text{power}) = -k.\log(\text{frequency})$$

where k is related to the fractal dimension, such that k=0 ($1/f^0$) correspond to a completely random stimulus of white noise, and higher values, of k=1,2, and 4 ($1/f^1$, $1/f^2$, $1/f^3$ and $1/f^4$) produce progressively more auto-correlate stimuli. Each element of the phase spectrum was set to a random valu between -Pi and +Pi, with the single exception that the phases of th fundamental components were set at 0, so that the image would appear as central white area against a black background. Figure 1 shows examples o stimulus pairs of different values of k and different sizes. Computation were carried out on a VAX11/780 computer, and stimuli were generated on Sperry 37 laser printer.

Procedure. Each subject saw stimuli of size 8x8, 16x16, 32x32 and 64x64, an within each size saw all possible pairs of fractal dimensions correspondin to $1/f^0$, $1/f^1$, $1/f^2$, $1/f^3$ and $1/f^4$. The design was therefore of a complet paired comparisons within sizes, with each fractal dimension occurrin equally often to right and left. The subjects therefore saw a total of 8 pairs of stimuli. Preference judgements were made on a six-point scale whic was reduced to a binary choice (left or right) before analysis.

Results.

For each subject and each stimulus size the set of all possible paire comparisons across fractal dimensions was analysed to obtain a single scor giving the preference for each fractal dimension relative to the other fracta dimensions; a score of +1 indicated that it was preferred to all othe dimensions and a score of -1 indicated that it was disliked relative to al other dimensions. The preference scores for each dimension were then subjected to a repeated measures analysis of variance.

Figure 2 shows the preference for each fractal dimension (expressed as the slope) for each size of stimulus. Analysis of variance shows highly significant effects of slope ($F(4,160)=5.18$, $p<.001$), which was due to a significant linear component ($F(1,160)=18.49$, $p<.001$), and no evidence of a quadratic or higher order trend. There was also a significant interaction between slope and stimulus size ($F(12,480)=6.25$, $p<.001$), which was almost entirely due to a linear x linear component ($F(1,480)=66.18$, $p<.001$). Because of the nature of the design it was not possible to compare preference for different matrix sizes.

Discussion.

We have shown that synthetic stimuli can be produced which are suitable for studies in experimental aesthetics, having the richness and structure characteristic of natural and artistic objects, but being sufficiently controlled to allow experimental manipulation.

Subjects show clear preferences for stimuli which differ in their fractal dimensionality. However in comparison with the work described by Gardner (1979) we could find no evidence for an optimal amount of complexity; preference increased linearly from the $1/f^0$ to $1/f^4$ stimuli. It is possible that the population results described here are hiding significant individual differences in preference (as has been described for simple geometric figures; McManus, 1980). That possibility is being investigated at present.

References.

Barnsley MF, Devaney RL, Mandelbrot BB, Peitgen H-O, Saupe D and Voss RF. The Science of Fractal Images, New York: Springer-Verlag, 1988.

Dorfman DD and McKenna H. (1966) Pattern preference as a function of pattern uncertainty. Canadian Journal of Psychology, 20: 143-153.

Gardner M. (1978) Mathematical games: white and brown music, fractal curves and 1/f fluctuations. Scientific American, 238: 16-31.

Mandelbrot BB. (1977) The Fractal Geometry of Nature, New York: WH Freeman.

McManus IC. (1980) The aesthetics of simple figures. British Journal of Psychology, 71: 505-524.

Voss R and Clarke P. (1975) 1/f noise in music and speech. Nature, 258: 317-318.

Figure 1. Shows two pairs of stimuli used in the study. a). Stimuli of size 16x16 with slopes of $1/f^0$ (left) and $1/f^4$ (right); b). Stimuli of size 64x64 with slopes of $1/f^0$ (left) and $1/f^2$ (right).

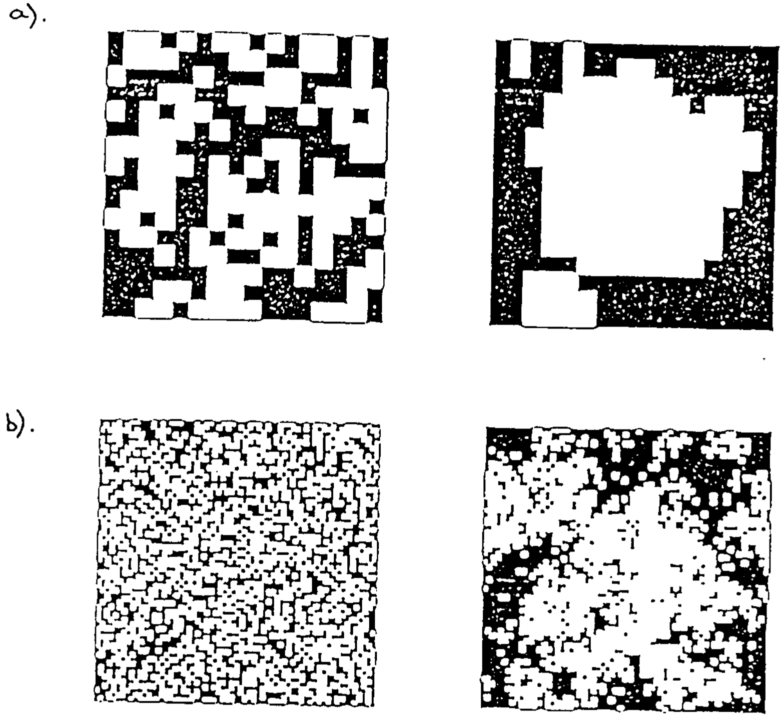

Figure 2. Shows the overall preferences of subjects for the stimuli of different fractal dimensions (slope) for each separate size of stimulus.