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## INFLUENCE OF GENETIC FACTORS ON PERCEPTION OF SELF-SIMILAR OBJECTS

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### *Abstract*

Fractal analysis research in psychology is based on the ideas and methods of fractal geometry of B. Mandelbrot. There exist theoretical and empirical reasons for genetic factors serving as a significant source of individual differences in visual perception of fractal stimuli. The present study concerned polymorphisms of *MAOA* and *DRD2* genes, which have been associated with a number of important psychological traits, and possibly influence the peculiar features of visual perception of fractals. The purpose of the study is to evaluate the influence of *MAOA* and *DRD2* genes on individual aesthetic preferences in perception of stimuli with different fractal dimensions. Sample: 124 people, aged 17–32 (M=19, SD=1.45). The method has been developed for the purpose of the study: the subjects ranked 20 flat images of different fractal dimensions (FD between 1.086–1.751) according to their subjective perception of these images' attractiveness. The genetic analysis revealed carriers of *MAOA* and *DRD2* allele genes that formed different subgroups. Methods of comparing the means: H-Kruskal–Wallis, ANOVA. Statistically significant differences were revealed among groups of respondents ($0.006 < p < 0.050$). The results of the study demonstrate the influence of polymorphisms of *MAOA* and *DRD2* genes on aesthetic preferences in perception of visual stimuli with fractal properties.



**Keywords:** Fractal, fractal dimension, aesthetic preferences, individual differences, MAOA gene, DRD2 gene.

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## 1. Introduction

The study of perception of self-similar objects in psychology is based on the ideas and methods of fractal geometry (Mandelbrot, 1982). Several issues have been discovered: a relationship between the assessment of subjective complexity and aesthetic appeal and the fractal dimension of incentives; psychophysiological and neurophysiological correlations between the perception of fractal objects; and an effect of fractal perception on the psychological status.

Some reliably reproducible data were obtained regarding the attractiveness of two-dimensional objects with the fractal dimension of 1.3–1.5, regardless of the mode of generation of the said fractals (Spehar, Clifford, Newell, & Taylor, 2003). This universal pattern is based on fractal properties of the natural and artificial environment of human beings, as well as the structural and functional organization of human beings at different levels of the hierarchy. However, genetic sources of individual differences in perception of self-similar objects have practically not been studied so far.

## 2. Problem Statement

The analysis of aesthetic appeal (Sprott,1993) showed that subjects preferred images with fractal dimension (FD) ranging from 1.1 to 1.5, which are characteristic, in particular, for clouds and seascapes. Taylor (2006) found that 90% of subjects preferred fractal patterns over non-fractal. These results have been reliably duplicated (Aks & Sprott, 1996; Abraham et al., 2003); the FD was found to be the main correlate of subjective assessment of complexity and aesthetic appeal of incentives (Mitina & Abraham, 2003).

The range of applicability of patterns discovered by Sprott also apply to works of art (Taylor, 2006), and to natural patterns, the perception of which is dominated by boundary contours (Hagerhall, Purcell, & Taylor 2004). There exist psychophysiological and neurophysiological correlates with the perception of complex fractal patterns (Taylor, Spehar, Van Donkelaar, & Hagerhall, 2011). The attractiveness of fractal forms is based on their similarity to various patterns found in nature (Mandelbrot, 1982; Peitgen & Richter, 1986). Human beings have been evolutionarily adapted to a fractally organized natural environment (Hagerhall et al., 2004).

The stimuli with medium fractal sizes usually judged to be the most attractive. Earlier studies focused on the universal character of this hypothesis. Scholars today are more interested in individual differences in peculiar factors defining the perception of fractals (Street, Forsythe, Reilly, Taylor, & Helmy, 2016). There exist theoretical and empirical reasons for genetic factors serving as a significant source of individual differences in visual perception of self-similar objects.

In this study, we chose MAOA and DRD2 genes as factors that were associated with a number of important psychological traits.

The MAOA gene encodes type A of the monoamine oxidase enzyme and is located on the X-chromosome (males normally are carriers of only one copy of the gene). Four alleles of this gene have been identified. Greater gene expression has been associated with alleles containing 3.5 or 4 tandem repetitions; and lower expression – with alleles of 3 or 5 (Sabol, Hu, & Hamer, 1998). The most frequently occurring alleles across all ethnicities are 3 and 4. The activity of the MAOA gene has been

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linked to the unipolar depressive disorder, the level of aggressiveness, asocial behaviour, psychopathic personality traits and emotional dysfunction. The MAOA gene polymorphisms have been interrelated with neuroticism, impulsivity, and some characteristics of self-regulation (Egorova & Chertkova, 2011; Egorova, Alfimova, Parshikova, & Pyankova, 2013).

Polymorphism of the dopamine receptor type 2 gene (DRD2) has also been considered. Dopamine is a neurotransmitter that transmits impulses between neurons, affecting many processes in the central nervous system. Some alleles of this gene have been associated with schizophrenia, addictive behavior (alcohol and drug addiction, smoking, gambling, risky behaviour, and eating disorders) (Munafo, Matheson, & Flint, 2007; Le Foll, Gallo, Le Strat, Lu, & Gorwood, 2009). When it comes to psychological characteristics that have not been identified as related to psychopathology or addiction, we have observed the association of polymorphisms of DRD2 gene with extraversion (Smillie, Cooper, Proitsi, Powell, & Pickering, 2010; Wacker, Chavanon, & Stemmler, 2006). Of note is a different structure of connections between peculiar characteristics of the dopaminergic function and various normal and pathological psychological properties, e.g., a decreased number of dopamine receptors of the second type ($D_2$) has been associated only with pathological manifestations of impulsivity (Colzato, Van den Wildenberg, Van der Does, & Hommel, 2010).

## 3. Research Questions

This study in molecular biology focuses on the search for possible genetic sources of perceptual variation of stimuli with fractal properties.

## 4. Purpose of the Study

The purpose of the study is to evaluate the influence of MAOA and DRD2 genes on individual aesthetic preferences in perception of two-dimensional visual stimuli with different fractal dimensions.

## 5. Research Methods

### 5.1. Sample

The sample contains 124 students of universities of Moscow aged 17–32 (M = 19, SD = 1.45; 47 boys and 76 girls; one respondent did not indicate his or her sex).

### 5.2. Methods

The method has been developed specifically for studying the characteristics of fractal perception (Pyankova, 2013, 2019). The subjects ranked 20 flat images of different fractal dimensions (FD between 1.086 to 1.751) according to their subjective perception of these images' attractiveness. The process of ranking allows to obtain a range of quantitative indicators for statistical analyses and evaluation of individual differences. The bank of stimuli was created using ChaosPro.exe fractal generator (Freeware). Fractal dimensions was assessed with the help of the box-counting method and Fractalyse software (CNRS, Laboratoire ThéMA, Université de Franche-Comté, France; www.fractalyse.org).

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The subjects gave their voluntary informed consent to provide their biological material for genetic analysis. The genotypes for 2 MAOA and DRD2 gene polymorphisms were determined. DNA was obtained from buccal epithelial cells.

The results were analyzed using Spearman's correlation coefficient and One-way ANOVA and the Kruskal–Wallis non-parametric criterion (H). The normality of the distribution was assessed using the Kolmogorov–Smirnov Test (Z). The statistical analysis was conducted using SPSS18 software.

## 6. Findings

### 6.1. Ranking of Stimuli in Terms of Attractiveness

The results of ranking of stimuli by the subjects (n = 121) show that:

– Mean fractal dimensions of pictures in each of twenty positions in the rating of attractiveness (FD of all first place pictures in each rating, then the second, etc) – 20 mean values from F1 to F20 for all subjects;

– Mean fractal dimensions in the attractiveness rating: first picture (FD1 = F1), first two pictures (FD2), first three pictures (FD3) and so on all the way to top ten pictures (FD10) – 10 indicators, from FD1 to FD10;

– the indicators for the second half of the attractiveness rating of stimuli were calculated in the same manner: the mean fractal dimension of the last 10 pictures in the attractiveness rating (Fin10), the last 9 pictures (Fin9) and so on up to the last picture's rating (Fin1 = F20 – 10 indicators, from Fin10 to Fin1.

Descriptive statistics of indicators from F1 to F20 have been shown in Table 1.

**Table 01.** Descriptive statistics

| Variables | Min | Max | M | SD | Variables | Min | Max | M | SD |
|---|---|---|---|---|---|---|---|---|---|
| F1 | 1.086 | 1.751 | 1.563 | 0.137 | FD1 | 1.086 | 1.751 | 1.563 | 0.137 |
| F2 | 1.138 | 1.751 | 1.575 | 0.121 | FD2 | 1.214 | 1.746 | 1.568 | 0.108 |
| F3 | 1.138 | 1.751 | 1.563 | 0.118 | FD3 | 1.234 | 1.715 | 1.565 | 0.094 |
| F4 | 1.086 | 1.751 | 1.581 | 0.117 | FD4 | 1.313 | 1.699 | 1.568 | 0.080 |
| F5 | 1.275 | 1.751 | 1.561 | 0.104 | FD5 | 1.337 | 1.679 | 1.566 | 0.072 |
| F6 | 1.086 | 1.751 | 1.545 | 0.133 | FD6 | 1.372 | 1.661 | 1.563 | 0.067 |
| F7 | 1.138 | 1.751 | 1.537 | 0.131 | FD7 | 1.339 | 1.654 | 1.559 | 0.062 |
| F8 | 1.086 | 1.751 | 1.549 | 0.125 | FD8 | 1.349 | 1.644 | 1.558 | 0.058 |
| F9 | 1.086 | 1.751 | 1.545 | 0.118 | FD9 | 1.367 | 1.635 | 1.556 | 0.055 |
| F10 | 1.086 | 1.751 | 1.540 | 0.133 | FD10 | 1.371 | 1.628 | 1.555 | 0.050 |
| F11 | 1.086 | 1.751 | 1.527 | 0.126 | Fin10 | 1.365 | 1.623 | 1.439 | 0.050 |
| F12 | 1.086 | 1.751 | 1.521 | 0.136 | Fin9 | 1.349 | 1.629 | 1.429 | 0.054 |
| F13 | 1.086 | 1.751 | 1.507 | 0.135 | Fin8 | 1.329 | 1.641 | 1.417 | 0.059 |
| F14 | 1.086 | 1.751 | 1.520 | 0.152 | Fin7 | 1.311 | 1.639 | 1.404 | 0.066 |
| F15 | 1.086 | 1.751 | 1.489 | 0.164 | Fin6 | 1.278 | 1.643 | 1.386 | 0.076 |
| F16 | 1.086 | 1.751 | 1.479 | 0.163 | Fin5 | 1.249 | 1.632 | 1.366 | 0.090 |
| F17 | 1.086 | 1.751 | 1.452 | 0.159 | Fin4 | 1.210 | 1.635 | 1.337 | 0.109 |
| F18 | 1.086 | 1.751 | 1.355 | 0.201 | Fin3 | 1.166 | 1.647 | 1.300 | 0.133 |
| F19 | 1.086 | 1.751 | 1.282 | 0.229 | Fin2 | 1.112 | 1.695 | 1.270 | 0.175 |
| F20 | 1.086 | 1.751 | 1.246 | 0.200 | Fin1 | 1.086 | 1.751 | 1.253 | 0.205 |

Note: The description of variables can be found in the text before the table, see beginning of Section 6.1.

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The mean fractal dimensions of pictures, ranked by attractiveness (from F1 to F20), gradually decreases from the first to the last picture in the rating – from 1.563 to 1.246. Average FD of the first 14 positions exceeded 1.5, but was less than 1.6 (recall that FD the images ranged from 1.086 to 1.751). This in general corresponds to the results of other studies described earlier. Individual differences were found in terms of dimensions of each position (indicators marked as F), and by averaged indicators (marked as FD or Fin) in the attractiveness rating.

The estimates of normal distributions of averaged fractal dimension indicators across the sample revealed deviations from normal values: these are the indicators FD1, FD8, FD10, Fin10–Fin9, and Fin5–Fin1 ($p < 0.05$). For these cases, when doing the genetic analysis we applied the H-Kruskal–Wallis criterion (analogue of the single-factor ANOVA).

### 6.2.Results of Genetic Analysis

The data were analyzed across the entire sample, and separately for men and women. It must be noted that the DNA was determined not in all the cases, so fewer people's data were included in the analysis than the total number of participants.

All subjects were divided into 3 subgroups according to the MAOA polymorphism: homozygotes and hemizygotes by allele 3, homozygotes and hemizygotes by allele 4, heterozygotes by alleles 3 and 4. Other types of alleles were not found in this sample. Most pronounced genetic effects could be found in the male subgroup. Since the MAOA gene is localized on the X chromosome, men are hemizygotes – carriers of the only one allele (3 or 4), and women are carriers of two, that is, they are homozygous (33 or 44) or heterozygous (34).

The results of the genetic analysis for MAOA are shown in Table 2 (there were a total of 22 persons with allele 3 only, 33 persons with allele 4 only, and 28 heterozygotes (alleles 3 and 4)). Significant differences were identified mainly in the first ten averaged rating indicators (FD3, FD6–FD10, Fin10–Fin9). Therefore, significant differences in fractal dimensions were revealed for more frequently preferred pictures in comparison with those that were less favoured by respondents. For subgroups of men (11 hemizygotes by allele 3; 18 hemizygotes by allele 4) and women (there were a total of 11, 15, and 28 homozygotes by alleles 3, 4, and heterozygotes respectively) no group differences were found between carriers of the MAOA gene. No such differences were found for the female subgroup.

**Table 02.** Analysis of differences between the subgroups of carriers of MAOA gene variations (3, 4 or 34)

| | **All sample H-Kruskal–Wallis** | | **All sample ANOVA** | | **Only males ANOVA** | |
|---|---|---|---|---|---|---|
| **Variables** | **Chi-square** | **p** | **F** | **p** | **F** | **p** |
| FD1 | 3.817 | 0.148 | 2.03 | 0.138 | 1.405 | 0.246 |
| FD2 | 4.534 | 0.104 | 2.388 | 0.098 | 1.869 | 0.183 |
| FD3 | 7.468 | 0.024* | 3.524 | 0.034* | 4.186 | 0.051 |
| FD4 | 3.994 | 0.136 | 2.372 | 0.100 | 3.861 | 0.060 |
| FD5 | 4.609 | 0.100 | 3.115 | 0.050* | 5.784 | 0.023* |
| FD6 | 6.850 | 0.033* | 3.085 | 0.051 | 3.763 | 0.063 |
| FD7 | 7.864 | 0.020* | 3.877 | 0.025* | 6.760 | 0.015* |
| FD8 | 8.842 | 0.012* | 4.444 | 0.015* | 7.031 | 0.013* |
| FD9 | 8.034 | 0.018* | 4.217 | 0.018* | 7.389 | 0.011* |

| | | | | | | |
|---|---|---|---|---|---|---|
| FD10 | 8.648 | 0.013* | 4.247 | 0.018* | 9.013 | 0.006** |
| Fin10 | 8.592 | 0.014* | 0.576 | 0.565 | 9.020 | 0.006** |
| Fin9 | 7.614 | 0.022* | 0.492 | 0.613 | 9.093 | 0.006** |
| Fin8 | 4.780 | 0.092 | 0.167 | 0.847 | 5.731 | 0.024* |
| Fin7 | 3.191 | 0.203 | 0.208 | 0.813 | 5.128 | 0.032* |
| Fin6 | 1.494 | 0.474 | 0.452 | 0.638 | 4.283 | 0.048* |
| Fin5 | 0.206 | 0.902 | 1.247 | 0.293 | 2.835 | 0.104 |
| Fin4 | 0.424 | 0.809 | 2.263 | 0.111 | .970 | 0.333 |
| Fin3 | 0.721 | 0.697 | 2.802 | 0.067 | .463 | 0.502 |
| Fin2 | 0.567 | 0.753 | 3.827 | 0.026* | 2.652 | 0.115 |
| Fin1 | 0.183 | 0.912 | 4.273 | 0.017* | .888 | 0.354 |

Note: * – $p < 0.05$, ** – $p < 0.01$.

The male subsample shows significant differences between the carriers of alleles 3 and 4 (men are carriers of only one allele of the MAOA gene) (see Table 2). The differences can also be found for indicators in the middle part of the rating of stimulus attraction. It is obvious that averaging more variables eliminates the role of random factors and helps detect the desired genetic effects.

Interestingly, the averages differ depending on whether the FD of most or least preferred images that are analyzed. For the first 10 most attractive images, a higher value of the preferred fractal dimension has been detected in the subgroup of homozygotes or hemizygotes by allele 3, associated with low expression of the MAOA gene; lower values were found in of homozygotes or hemizygotes by allele 4; and medium values – in heterozygotes 34 (only women can be heterozygous). For the ten indicators of least preferred pictures in the second half of the rating, the picture is opposite: the average FD is higher in the subgroup of homozygotes or hemizygotes by allele 3, lower – in homozygotes or hemizygotes by allele 4, and medium – in heterozygotes 34. It is clear that the indicators were divided into two equal subgroups of 10 each purely by chance, but the pattern is clear: reduced expression of MAOA has been associated with greater attractiveness of higher fractal dimensions, while lower attractiveness was shown for images with lower fractal dimensions.

In the DRD2 gene, humans may have a single nucleotide substitution. There are 2 alleles in the population – with this substitution (A1), or without it (A2). The subgroups were formed in accordance with possible combinations of variants: A1A1, A2A2, A1A2 (n = 4, 56 and 20 respectively). Since variant A1A1 was found only 4 times, in the statistical analysis only the subgroups with genetic variants A2A2 and A1A2 were compared. Significant differences were found between these subgroups for indicator FD1 (the fractal dimension of the first most attractive picture in the rating) and indicator FD2 (the average FD of the first two pictures in the ranking). The H-Kruskal–Wallis test showed $p = 0.005$ for FD1, and $p = 0.026$ for FD2. The ANOVA method revealed intergroup differences in the same variables FD1 and FD2 ($p = 0.033$ and $p = 0.023$, respectively). At the same time, a lower fractal dimension has been associated with the absence of the this single nucleotide substitution (variant A2) for FD1 and FD2 and in general for all the first 10 positions in the attractiveness rating; for the last 10 positions, the situation is the opposite, with option A2, the fractal dimension is higher (although there are no significant differences). The pattern is absolutely the same as in the case of the MAOA gene.

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## 7. Conclusion

The results of the study demonstrate the influence of polymorphisms of MAOA and DRD2 genes on aesthetic preferences in perception of visual stimuli with fractal properties. So, we may draw a conclusion that individual differences in perception of two-dimensional self-similar images are of genetic character to some extent. Our results show that average indicators of fractal dimensions of stimuli, ranked by the degree of subjective attractiveness, are most informative indicators..

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