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# FRAGRANCE AS A SOURCE OF WELL-BEING: FRACTAL STUDY USING ECG TIME SERIES

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***Abstract:*** This work reports on the study of the effects of fragrance as stimulus on six subjects. Their ECG signals are acquired before and while inhaling the fragrance of sandal wood. The ECG time series are analysed in the light of fractal based nonlinear technique. For this purpose Hurst's Rescaled range analysis method has been utilized. The results are interesting and may be useful in the development of fragrance therapy.

***Keywords:*** fragrance; ECG time series; fractal; non-linear technique; Hurst's Rescaled range analysis method

## I. INTRODUCTION

Fragrance has its own importance from time immemorial and it has been used consciously or unconsciously to create an environment of stress relaxation or in other words to develop a feeling of well-being. Aroma has a great influence on psychological conditions like mood, emotion, motivation and memory [1-2]. Scientific investigations in the area of neuroscience are coming up to study the effectiveness of different stimuli on ANS. This has been tried with recent tools of analysis of non-linear complex biological signals e.g. ECG.

Electrocardiogram (ECG) is the record of the electrical activity of the heart. Different kinds of external stimulation on heart activity can be studied by analyzing the ECG signal. Emotion elicited by olfactory stimuli [3-5] is noteworthy to mention.

Olfactory stimulus has effects on physiological state like blood pressure, heart rate, immune system and hormones [6-10]. Such stimulus can be used to reduce the level of anxiety on palliative care patients [11]. It is used to treat sleep apnea [12] on human. Olfactory stimulation with scent of grapefruit oil and lavender oil affect autonomic neurotransmission and elicit changes in lipolysis, thermogenesis, food intake, body weight, blood pressure, kidney, adrenal gland, brown adipose tissue in rats [13-17]. The sense of fragrance affects ANS. The changes in ANS can be observed minutely in ECG time series. ECG signals are very much complex and non-linear. ECG signal has self-similarity or Fractal nature. A fractal is a natural phenomenon or a mathematical set that exhibits a repeating pattern or self-similar pattern revealing at every scale. Scaling exponents or fractal dimension decides the scaling rules. Regular structures have integer dimension whereas, complex self-similar objects have non-integer dimension. In this work, effect of sandal wood fragrance on ANS has been studied. For this purpose, ECG signals are acquired from six subjects. Some of the usual DSP methods are unable to decipher the intricate complexity of non-linear signal modified by input of emotion elicited stimuli. Non-linear dynamics based on fractal approach is sensitive to capture even small perturbation. In this work, Hurst's Rescaled Range Analysis method [18-19] has been utilized which focuses on finding the Fractal Dimension of the time varying ECG signal.

## II. METHOD

ECG signals are acquired using POLYPARA module with a sampling rate of 200 samples per second from 6 subjects. All the 6 subjects are healthy and are under no medical treatment. All participants are allowed to sit in a relaxed position. Normal ECG signals are recorded using POLYPARA module for 5 minutes. They are then allowed to relax for 15 minutes. Next each subject is allowed to inhale a fragrance of sandal wood separately while ECG signals are recorded for 5 minutes.

## III. FRACTAL

### A. *Hurst's Rescaled Range Method*

This method is simple and robust. For discrete time series, $x_t$ of dimension N, mean $\tilde{x}(N)$; standard deviation S(N) and cumulative departure X(n,N) [18-19], are calculated as given in eqn.(1), eqn.(2) and eqn.(4) below,

$$\tilde{x}(N) = \sum \frac{x_t}{N} \quad (1)$$

$$S(N) = [\frac{1}{N}\sum (x_t - \tilde{x}(N))^2]^{\frac{1}{2}} \quad (2)$$

R(N) denotes the range of cumulative departure

R(N)=max[x(n,N)]-min[x(n,N)] (3)

Cumulative departure is given by

$$X(n,N) = \sum (x_t - \tilde{x}(N)), \quad 0 \le n \le N \quad (4)$$

$$\frac{R}{S} = n^H \quad (5)$$

The fractal dimension D [18-19] is determined as

D = 2 - H (6)

When Hurst exponent lies in between 0.5 and 1, this means the time series is persistent and the earlier observation has a positive correlation with the following observation [20-21]. If Hurst exponent lies in between 0 and 0.5, it means the

data series is anti-persistent and the earlier observation has a negative correlation with the following observation [20-21]. In this work, the entire time series is divided into 5 sections each of 5000 samples in length. Rescaled range analysis of ECG time series is done over each slot of 5000 samples and H and D values for each slot are tabulated in the following tables.

## IV. RESULTS AND DISCUSSION

Table 1: Hurst Exponent (H) and Fractal Dimension (D) for Normal ECG

| Subject | 1st slot of 5000 samples | | 2nd slot of 5000 samples | | 3rd slot of 5000 samples | | 4th slot of 5000 samples | | 5th slot of 5000 samples | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H | D | H | D | H | D | H | D | H | D |
| 1 | 0.6174 | 1.3826 | 0.4059 | 1.5941 | 0.4034 | 1.5966 | 0.3992 | 1.6008 | 0.3973 | 1.6027 |
| 2 | 0.6357 | 1.3643 | 0.5548 | 1.4452 | 0.5366 | 1.4634 | 0.5973 | 1.4027 | 0.5123 | 1.4877 |
| 3 | 0.5587 | 1.4413 | 0.5344 | 1.4656 | 0.5393 | 1.4607 | 0.5186 | 1.4814 | 0.5441 | 1.4559 |
| 4 | 0.5215 | 1.4785 | 0.3499 | 1.6501 | 0.3596 | 1.6404 | 0.3554 | 1.6446 | 0.3690 | 1.6310 |
| 5 | 0.5078 | 1.4922 | 0.3535 | 1.6465 | 0.3353 | 1.6647 | 0.3356 | 1.6644 | 0.3322 | 1.6678 |
| 6 | 0.5863 | 1.4137 | 0.4290 | 1.571 | 0.4298 | 1.5702 | 0.4203 | 1.5797 | 0.4187 | 1.5813 |

Table 2: Hurst Exponent (H) and Fractal Dimension (D) for ECG with Fragrance as Stimulus

| Subject | 1st slot of 5000 samples | | 2nd slot of 5000 samples | | 3rd slot of 5000 samples | | 4th slot of 5000 samples | | 5th slot of 5000 samples | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H | D | H | D | H | D | H | D | H | D |
| 1 | 0.6150 | 1.3850 | 0.4040 | 1.5960 | 0.4045 | 1.5955 | 0.3980 | 1.6020 | 0.4034 | 1.5966 |
| 2 | 0.6324 | 1.3676 | 0.4509 | 1.5491 | 0.4526 | 1.5474 | 0.4520 | 1.5480 | 0.4922 | 1.5078 |
| 3 | 0.5668 | 1.4332 | 0.5400 | 1.4600 | 0.5415 | 1.4585 | 0.5600 | 1.4400 | 0.5389 | 1.4611 |
| 4 | 0.5327 | 1.4673 | 0.3559 | 1.6441 | 0.3546 | 1.6454 | 0.3678 | 1.6322 | 0.3543 | 1.6457 |
| 5 | 0.5578 | 1.4422 | 0.3738 | 1.6262 | 0.3667 | 1.6333 | 0.3714 | 1.6286 | 0.3775 | 1.6225 |
| 6 | 0.5879 | 1.4121 | 0.4300 | 1.5700 | 0.4346 | 1.5654 | 0.4441 | 1.5559 | 0.4179 | 1.5821 |

From Table 1 and Table 2, some interesting observations are made. There is a decreasing trend of persistent nature with fragrance as stimulus when compared with normal ECG in the first, second and fourth time slots for the first subject, but the same subject has shown an opposite trend in the third and fifth time slots. The second subject has shown decreasing trend of persistent nature with fragrance as stimulus over all the time slots. The third subject has shown an increasing trend of persistent nature with fragrance as stimulus in all time slots except the last one. The fourth subject has shown an increasing trend of persistent nature with fragrance as stimulus in the first, second and fourth time slots, but the same subject has shown an opposite trend in the third and fifth time slots just as the first subject. The fifth subject has shown increasing trend of persistent nature with fragrance as stimulus over all the time slots. The sixth subject has shown an increasing trend of persistent nature with fragrance as stimulus in all time slots except the last one just as the third subject. These facts indicate the intricate complexity of ECG time series with fragrance as stimulus over all the five time slots.

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Table 3: Average values of H and D of six subjects

| Subject | Normal ECG | | ECG with Fragrance | |
|---|---|---|---|---|
| | H | D | H | D |
| 1 | 0.44464 | 1.55536 | 0.44498 | 1.55502 |
| 2 | 0.56734 | 1.43266 | 0.49602 | 1.50398 |
| 3 | 0.53902 | 1.46098 | 0.54944 | 1.45056 |
| 4 | 0.39108 | 1.60892 | 0.39306 | 1.60694 |
| 5 | 0.37288 | 1.62712 | 0.40944 | 1.59056 |
| 6 | 0.45682 | 1.54318 | 0.46290 | 1.53710 |

From Table 3 it is observed that first, fourth, fifth and sixth subjects have shown similar effects of fragrance in their ANS. Each of them has anti-persistent nature before inhaling the fragrance. While inhaling the fragrance, each is showing anti-persistent nature but the trend is moving towards persistency. This implies fragrance has caused their ECG signals to move towards regular patterns and smoothness. The third subject has persistent nature before inhaling the fragrance and moreover this subject is showing more persistency while inhaling the fragrance. So, this subject has also shown that fragrance has caused the ECG signals to move towards regular patterns and smoothness. The second subject on the other hand has shown

persistent nature before inhaling the fragrance. But, this subject has shown anti-persistent nature while inhaling the fragrance. So, this subject has shown opposite result that is fragrance has caused the ECG signal to become more complex and it has moved towards irregular patterns and less smoothness.

## V. CONCLUSION

The exposure to sandal wood fragrance has shown an increasing trend towards persistency of ECG time series for the five subjects. One of the subjects has shown opposite trend. These results indicate that sandal wood fragrance has a relaxant effect and as such this method can be considered as a tool for fragrance therapy.

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