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Fuzzy Model for Smoking Cessation and Cortisol Awakening Responses

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Abstract. The purpose of study was smoking is associated acutely with elevated Cortisol levels. However, the results of comparisons of Cortisol levels in smokers and nonsmokers have been inconsistent and the significance of Cortisol responses in smoking cessation is unclear. Smoking cessation was accompanied by an abrupt decrease in salivary Cortisol and this was sustained over the abstinence period Cortisol. There was marginal association between the decrease in Cortisol and smoking relapse rates. In many practical applications, it turns out to be useful to use the notion of fuzzy transform: once we have functions $A_1(x) \geq 0$, ……, $A_n \geq 0$, with $\sum_{i=1}^{n} A_i(x) = 1$, we can then represent each function f (x) by the coefficients $F_i = (\int f(x).A_i(x)dx) / (\int A_i(x)dx)$. Once we know the coefficients F_i, we can (approximately) reconstruct the original function f(x) as $\sum_{i=1}^{n} F_i.A_i(x)$. The original motivation for this transformation came from fuzzy modeling, but the transformation itself is a purely mathematical transformation. Thus, the empirical successes of this transformation suggest that this transformation can be also interpreted in more traditional (nonfuzzy) mathematics as well. Such an interpretation is presented in this paper.

Keywords: Cortisol, surgery, f-transform, smoking cessation, cortisol awakening response

AMS Mathematics Subject Classification (2010): 90B22

1. Introduction

Tobacco Smoking has a wide range of biological effects that contribute to its negative impact on health [1,2,3]. The relationship between smoking and Cortisol is important for at least three reasons. First, the HPA axis is implicated in addictive processes, as discussed by other contributions to this special issue. Second, heightened levels of Cortisol have a range of adverse effects on biological processes relevant to long-term health. Third, Cortisol is highly sensitive to psychological stress [4]. Cortisol levels are high in the early morning and diminish through the day, sometimes with a small secondary peak after a mid-day meal. There is growing evidence that the Cortisol change over the first hour after awaking represents a distinct psychobiological phenomenon that is under different control mechanisms from Cortisol over the remainder of the day [5, 6]. In the study described here, we therefore present separate results for Cortisol over the day and the Cortisol awakening response. The F-transform of function f is a vector with weighted local mean values of f as components. The first step in the definition of the F-transform of f: X →R is a selection of a fuzzy partition of universal set X by a finite set of basic functions $A_1(x) \geq 0, \ldots, A_n(x) \geq 0$ (1)

which are continuous and satisfy the condition $\sum_{i=1}^{n} A_i(x) = 1$.

2. Fuzzy transform

Basic functions are called membership functions of respective fuzzy sets, or, alternatively, granules, information pieces, etc. Their choice reflects the type of uncertainty which is related to the knowledge of x. Once the basic functions are selected, we define the F-transform of a continuous function f : X → R as a vector$(F_1, \ldots, F_n)$, where

$$F_i = \left(\int f(x).A_i(x)dx\right) / \left(\int A_i(x)dx\right). \quad (2)$$

F-transform satisfies the following properties:

(i) y= F_i minimizes $\int_a^b (f(x)-y)^2 A_i(x)dx$

(ii) for a twice continuously differentiable function f, $F_i = f(x_i) + O(h_i^2)$, where h_i is the length of the support of A_i.

F-transform is used in applications as a "skeleton model" off. This model provides a compressed image if f is an image[7], values of a trend if f is a time series [8], a numeric model if f is used in numeric computations (integration, differentiation) [9], etc. Once we know the F-transform components Fi, we can (approximately) reconstruct the original function f as $\bar{f}(x) = \sum_{i=1}^{n} F_i A_i(x)$ (3)

In [1], the formula (3) is called the F-transform inversion formula. The formula (3) represents a continuous function that approximates f. Under certain reasonable conditions, a sequence of functions represented by (3) uniformly converges to f (see [10] for more details).

3. Example

The study group participated in a laboratory together with ambulatory blood pressure and heart rate monitoring over a working day. In addition, they collected saliva samples on a workday according to after waking 30 minutes later. Complete data for the eight timed samples were available from 167 participants over the working day 15 smokers and 152 nonsmokers. These individuals did not differ from the remainder on any socio demographic characteristics. Smokers, nonsmokers did not differ significantly in age or gender distribution. Fig. 1 summarizes the mean levels of Cortisol in smokers and nonsmokers over the working day. Repeated measures analysis of variance with smoking status as the between-subject factor and time as the within-subject factor revealed main effects for smoking status and time of day, with no interaction between the two. It can be seen that 'Cortisol showed the expected decline over the day, but that levels were slightly higher throughout in smokers than nonsmokers. This repeated measures analysis did not include covariates subsequently averaged the Cortisol values and compared smokers and nonsmokers in an analysis of covariance with age gender, grade of employment.

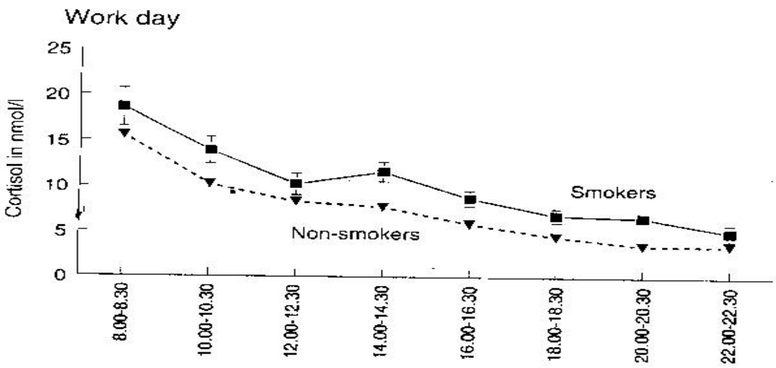

Figure 1: Mean cortisol at eight times of the day and evening in smokers(solid line) and non-smokers(dashed line), sampled over a working day.

Let us give an example of the F-transform of

(Non-Smokers) $f_1(x) = \frac{2}{2+x}$, (Smokers) $f_2(x) = \frac{2}{1+x}$ with respect $A_1, \ldots, A_4$. For simplicity, we assume that basic functions $A_1, \ldots, A_4$ are of trapezoidal shape and constitute a uniform partition of [0,8]. Their analytical representation is as follows:

$$A_1(x) = \begin{cases} 0, otherwise \\ 1, x \in [1,2] \\ 3-x, x \in [2,3] \end{cases} \qquad A_2(x) = \begin{cases} x-2, x \in [2,3] \\ 1, x \in [3,4] \\ 5-x, x \in [4,5] \\ 0, otherwise \end{cases} \tag{4}$$

$$A_3(x) = \begin{cases} x-4, x \in [4,5] \\ 1, x \in [5,6] \\ 7-x, x \in [6,7] \\ 0, otherwise \end{cases} \qquad A_4(x) = \begin{cases} x-6, x \in [6,7] \\ 1, x \in [7,8] \\ 0, otherwise \end{cases}$$

Corresponding Fuzzy function for above figure 1.

The original motivation for F-transform came from fuzzy modeling [11]. For example, in the situation corresponding to the inverse F-transform, we have n rules

If x is A_1 then y = F_1,
If x is A_n then y = F_n (5)

These rules are Takagi-Sugeno (TSK) rules with singleton (constant) right-hand sides. For TSK rules, the value corresponding to a given input x is $\bar{f}$ (x) = $\sum_{i=1}^{n} F_i A_i(x) / \sum_{i=1}^{n} A_i(x)$. Since $\sum_{i=1}^{n} A_i(x)=1$, we get formula (3).

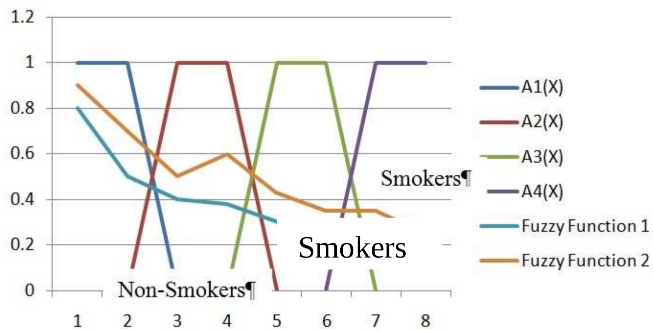

Figure 2: a graphical representation of the basic functions A_1, . . . ,A_4, of the function (Non-Smokers) f_1 (x) and (Smokers) f_2(x).

The purpose was to show that this type of modeling can be as useful in applications as more traditional techniques such as Fourier transform and wavelet transform. Moreover, F-transform has a potential advantage over Fourier and wavelet transforms: in contrast to the purely mathematical basic functions used in Fourier and wavelet transforms, the basic functions Ai in a fuzzy partition usually come from natural language terms like “low” or “high” (for a detail eddescription of fuzzy modeling, see, e.g., [12]). Just like any other tool of applied mathematics, F-transform is not a panacea. It is more successful in some problems, and in other problems, it is less successful. It is therefore desirable to combine F-transform with other mathematical tools, so as to combine relative advantages of different techniques. For combining F-transform with other mathematical tools, it is desirable to come up with a purely mathematical (non-fuzzy) interpretation for this transform.

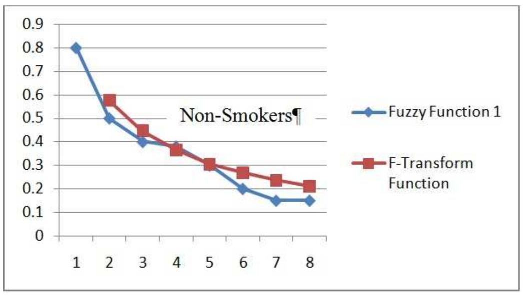

Figure 3: Corresponding-transform function for fuzzy function 1 f_1(x) of mean cortisol at eight times of the day and evening in non-smokers sampled over a working day.

By (2) the values of the components F_1,… $F_7$of the function (Smokers) f_2(x) of the F-transform are F_1=0.8109, F_2=0.576, F_3=0.4463, F_4=0.3648, F_5=0.3083, F_6=0.2672, F_3=0.2356.

By (2) the values of the components F_1,… F_7 of the function (Non-Smokers) $f_1(x)$ of the F-transform are F_1=0.5754, F_2=0.4465, F_3=0.3646, F_4=0.3048, F_5=0.2671, F_6=0.2356, F_7=0.2107.

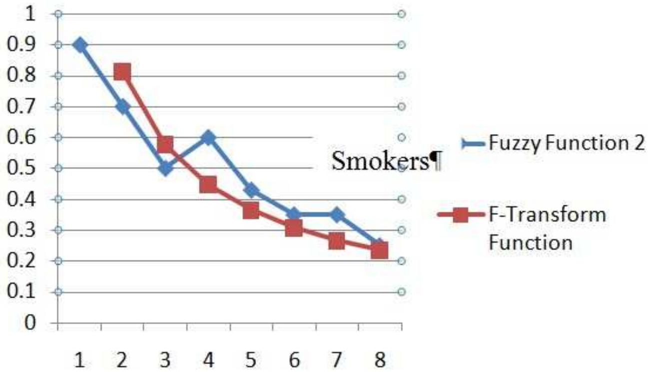

Figure 4: Corresponding F-transform function for fuzzy function 2 $f_2(x)$ of mean cortisol at eight times of the day and evening in smokers sampled over a working day.

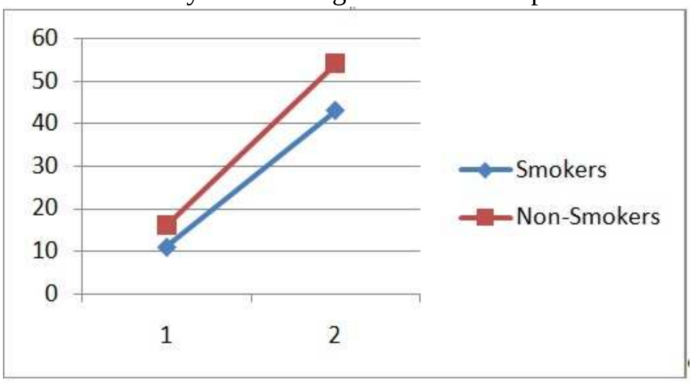

Figure 5: Mean cortisol on Waking (Wake) and 30 min later (+30) on a work day in smokers and non-smokers.

Once we know the F-transform components Fi, we can (approximately) reconstruct the original function f (Smokers and Non-Smokers) as f(x) = $\sum_{i=1}^{n} F_i A_i(x)$

4. Conclusion

The Mathematical model also stresses the same cumulative effects of Smokers and Non smokers conditions, which are matched with F-Transform (See Fig.2, 3 and 4). The results of these analyses indicate that Cortisol levels are elevated in everyday life among smokers compared with nonsmokers. The time and Cortisol levels are compared with smokers and non-smokers periods (Fig. 4) show that these are a vast difference between the time periods in both the cases. The results coincide with the mathematical and medical report. A similar modification is described in a more general situation of fuzzy modeling.

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