

# Suicides and the lunar cycle

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## Resumen

The existence of lunar influence on the frequency of suicide is tested by means of a permutation test. A total of 897 suicide deaths reported by the Anatomical Forensic Institute of Madrid were analyzed by a permutation test, a direct application of Fisher's ideas. Noteworthy in this study are the testing method used and the accuracy of timing of the deaths. Both factors provide firm ground for our conclusion: there appears to be no relationship between lunar phases and suicide.

**Keywords:** Suicide; synodic cycle; permutation tests; computer-intensive tests.

## 1 Introduction

The hypothesis of cosmic influence on human behaviour has long been entertained. Tradition and folklore in many cultures have considered the Moon the perfect target to correlations with extraordinary events or deviant behaviours, because of its proximity to the Earth and the simplicity of observation of its synodic (four-phase) cycle. Those correlations have been investigated and, in most cases, found illusory. The following is a partial list of studies investigating the lunar influence on various matters: on labour absenteeism, [20]; on accidents and physical diseases; [2]; on births, [21] and [9]; on crisis calls, [13], [1]; on suicide deaths, [18], [12]; and on suicide attempts, [11], [12], [10]. Relevant studies in Spain about moon phases and suicide include [4], and [17]. Other informative articles about traditional lunar misconceptions are by [19] and [14].

We find the extensive review of [10] to be the most complete. They are very clear in their conclusions: the hypothesis of a relationship between the moon's phases and human behaviour is not supported by the evidence of a large number of studies conducted by many independent investigators all over the world. In spite of this body of evidence, we want to test again for an hypothetical lunar influence on deaths by suicide. Our study departs from previous work in the field in two aspects, the use of very accurately timed data and the use of a novel testing method.

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Tabla 1: Day of synodic cycle, number of suicides, and ratio observed/expected suicides under the hypothesis of no lunar effect

Day	Suicides	$\frac{Obs}{Exp}$	Day	Suicides	$\frac{Obs}{Exp}$	Day	Suicides	$\frac{Obs}{Exp}$
1	27	0.889	11	26	0.855	21	36	1.184
2	25	0.823	12	32	1.053	22	30	0.987
3	34	1.119	13	29	0.954	23	38	1.250
4	29	0.954	14	33	1.086	24	28	0.921
5	31	1.020	15	24	0.789	25	23	0.757
6	32	1.053	16	34	1.119	26	34	1.119
7	28	0.921	17	29	0.954	27	24	0.789
8	33	1.086	18	30	0.987	28	29	0.954
9	32	1.053	19	35	1.151	29	35	1.151
10	36	1.185	20	27	0.888	30	14	0.881

## 2 Method

### 2.1 Data

In a previous investigation [6] found that completed suicides in Madrid exhibited different patterns in time: strong circadian, weekly, monthly and weak seasonal changes were observed. However, possible lunar influence was not taken into account.

The source of the data used was the Anatomical Forensic Institute (AFI) of Madrid. All corpses suspected of unnatural death in the city of Madrid are brought to the AFI, where an autopsy is performed to ascertain the real cause of death and its likely aetiological motivation (criminal, suicidal, or accidental). The total number of deaths ascribed to suicide was 897 (595 men and 302 women) for the three-year period 1990–1992. The exact date and time of death for each suicide is established by the AFI, with a claimed accuracy of plus or minus 15 minutes.

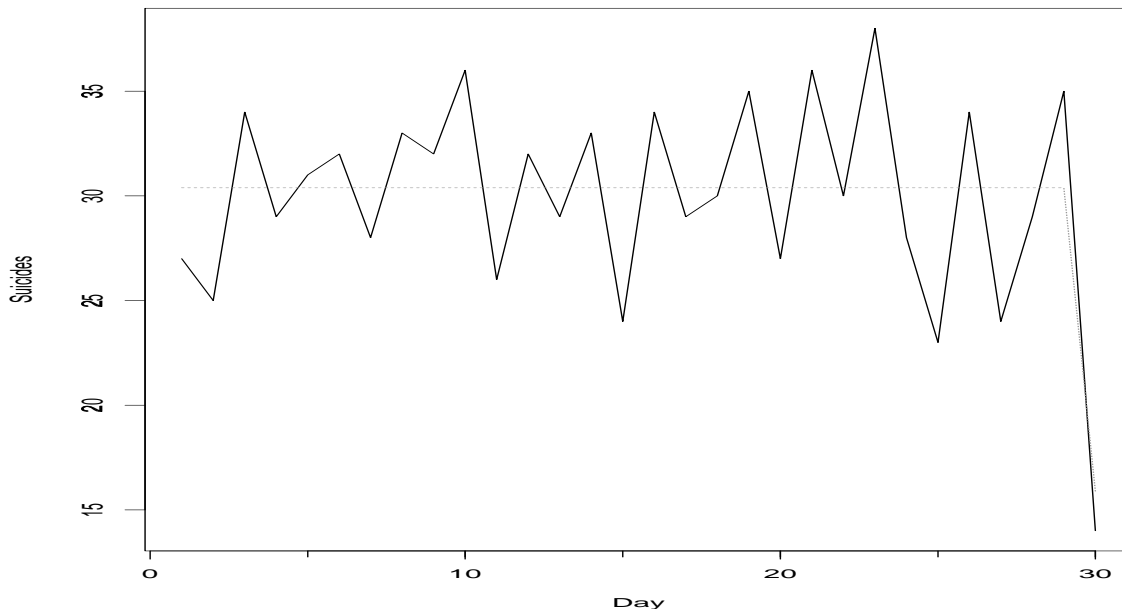
### 2.2 Lunar cycle

For the purposes of this study, the 1096 consecutive days from January, 1, 1990 to December, 31, 1992 were divided into 37 synodic cycles. The lunar cycle, the time it takes for the moon to complete an orbit around the earth, is 29.523 days long. We built a Buys-Ballot table, allocating each of the 897 cases to one of thirty cells. In order to do that, lunar days rather than solar days were taken into account.

The allocation of suicides to lunar days was made by subtracting from the exact date and time of the suicide the exact date and time of the new moon, and then dividing by 24 hours. The processed data is summarized in Table 1 and displayed in Figure 1. Collapsing the 37 cycles in a Buys-Ballot table effectively averages out unwanted sources of variation, such as "day-of-week" effects which might exist in the data.

Notice that the day 30 has a smaller number of observed suicides. Since, as mentioned before, the lunar cycle is 29.523 days long, the expected number of suicides in the days 1-29 (under the hypothesis of no lunar influence) is  $897/29.523$ , while for the day 30 is  $897 \times 0.523/29.523$ . Using the ratio Observed/Expected suicides corrects

Figura 1: Observed versus expected suicidal acts for each day in the synodic cycle.



this anomaly, except for the fact that the cell corresponding to the day 30 has larger variance, for which we have not attempted to correct.

### 3 Procedure

#### 3.1 Smoothing concepts.

A short summary of results on smoothing is presented here for completeness and to introduce notation. The mathematically inclined reader is referred to [3], [5] or [7], among the many comprehensive texts dealing with smoothing issues.

Let  $(y_i, x_i), i = 1, \dots, n$  be a sample from a bivariate variable, and assume that  $y_i = f(x_i) + \epsilon_i$ , where the  $\epsilon_i$  are assumed independent with mean zero and common variance. If  $f(x)$  were a linear function of  $x$  we would have the standard linear model with one regressor, but a much more flexible class of functions can be postulated, requiring only conditions such as continuity of  $f$  and perhaps of some of its derivatives.

Several methods have been put forward for the estimation of  $f$  within the framework of nonparametric regression. A cubic *spline* with nodes at  $\psi_1, \dots, \psi_k$  is a piecewise polynomial with the first two derivatives continuous and a third derivative which is constant within each interval  $(\psi_i, \psi_{i+1})$ . It can be shown that the function  $g(x)$  minimizing

$$\sum_{i=1}^n (y_i - g(x_i))^2 + \lambda \int [g''(x)]^2 dx, \quad (1)$$

is a cubic spline, with nodes at  $(x_1, \dots, x_n)$ . The first term in [1] requires  $g(x)$  to pass

close to the points  $(x_i, y_i)$ , while the second penalizes departures from linearity, thus forcing  $g(x)$  to be smooth. The parameter  $\lambda$  specifies the desired trade-off between goodness of fit and smoothness: the larger  $\lambda$ , the smoother  $g(x)$  is.

The parameter  $\lambda$  can be chosen from the data. Let  $f_\lambda^{(-i)}(x)$  be the minimizer of [1], for given  $\lambda$ , when the  $i$ -th point is dropped from the sample. The cross-validated sum of residuals is defined as

$$CV(\lambda) = \min_{\lambda} \sum_{i=1}^n (y_i - f_\lambda^{(-i)}(x_i))^2 \quad (2)$$

and the  $\lambda$  chosen by cross-validation is the value  $\lambda_{CV}$  which minimizes [2]. It turns out that there are extremely fast algorithms for the computation of  $\lambda_{CV}$  (see for example [8]).

### 3.2 The testing method.

Consider a sequence with a natural order (most typically, data values ordered in time). We therefore have a sample such as  $(i, y_i), i = 1, \dots, n$ . In our case,  $i = 1, \dots, 30$  and  $y_i$  are the ratios of observed versus expected suicides in each of the 30 days of the synodic cycle (which we refer to below as the "daily suicide rate").

We are interested in testing for randomness in that sequence against a general alternative of "smooth" evolution in time, with no predefined pattern, which might be ascribed to lunar influence.

In the absence of any pattern along time, the daily suicide rate should fluctuate randomly around a fixed level. If we fit a *spline* to  $(i, y_i), i = 1, \dots, 30$  choosing  $\lambda$  by cross-validation (as defined just below [2]), the fitted curve should be a nearly straight line, a curve of "low complexity", because there is no structure to adapt to. Should a pattern exist, we can expect the *spline* to capture it. A natural idea then is to measure how much the complexity of the fitted *spline* deviates from what would be expected when fitting an entirely random sequence. Were the complexity sufficiently larger, we would take it as evidence of structure in the data and reject the hypothesis of complete randomness.

We thus confront the problem of determining whether a fitted *spline* is "complex" enough. Several possibilities exist: [15] proposes a test for no effect in a nonparametric regression setting; following [16] we could try to compute a measure of complexity for the fitted spline. We have followed an approach which uses as a test statistic  $\lambda_{CV}$ , as a *proxy* of the complexity of the fitted *spline*: the smaller  $\lambda_{CV}$ , the more complex the curve is.

To obtain a yardstick against which to measure the value of the test statistic, we resort to resampling after permutation; that is, we generate a large number  $K$  of permutations of the  $y_i$ 's,  $i = 1, \dots, 30$ . For each permutation  $k = 1, \dots, K$  we compute  $\lambda_{CV}^{(k)}$ ; each  $\lambda_{CV}^{(k)}$  can then be seen as arising from a distribution which generates data exactly like ours, only with a random ordering. Should our original data be random,  $\lambda_{CV}$  should come from the same distribution than the  $\lambda_{CV}^{(k)}$ .

Since for realistic sizes of  $n$  complete enumeration of all the  $n!$  permutations is out of the question, we simulate a few hundreds or thousands. The proposed test is described in Table 2.

A more detailed description of the test, its rationale, and simulations giving an appraisal of its power can be found in [22].

Tabla 2: Permutation test.

1. For the given sample  $(t_i, y_i), i = 1, \dots, n$  fit a cubic *spline* and compute  $\lambda_{CV}$ .
2. For  $k = 1, \dots, K$  do the following:
  - (a) Shuffle the  $y_i$  to generate a randomly ordered sample  $y_{i_k}$ .
  - (b) Fit a cubic spline to the  $y_{i_k}$  and compute  $\lambda_{CV}^{(k)}$
3. Reject the hypothesis of randomness at the chosen level of significance if  $\lambda_{CV}$  is among the smallest  $\lambda_{CV}^{(k)}$ .

## 4 Results

Fitting a cubic spline to the data gives an estimated  $\lambda_{CV}$  of 0.01924. The data and fitted spline can be seen in Figure 2. It is apparent that the spline fitted is almost a straight line—in a sense, the smoothest possible function. This points to a lack of structure in the data, which is confirmed in the following.

To judge whether this value is small enough to be significant (recall that the more structure the spline is able to capture, the smaller the  $\lambda_{CV}$  chosen by cross-validation is), we have performed one thousand random shufflings of the data, computing each time  $\lambda_{CV}^{(k)}, k = 1, \dots, 1000$ . The empirical distribution of these  $\lambda$ 's is shown in Figure 3. Reference to it show that  $\lambda_{CV} = 0.01924$  is by no means small: far from being among the smallest, is in fact the 64th largest among one thousand. The hypothesis of randomness cannot therefore be rejected even at the (ludicrously high) 93.6% significance level.

## 5 Conclusions

We failed to uncover any significant relationship between the synodic cycle and the suicide rate, thus adding our study to the extensive list of investigations who analyzed this issue with similar results.

Several remarks are worth making regarding both the method and the data.

1. How accurate is the data set used? As pointed out by [11], time of death is often difficult to determine. The Anatomical Forensic Institute claims that the approximation in the time of death is plus or minus 15 minutes. We have no means of checking whether this claimed accuracy is real in all cases, but the timing is probably as good as one can possibly get.
2. What is the point, it might be asked, in using a test method such as the one proposed? Would not a simple chi-squared goodness-of-fit test be as good?

The answer is "Not always." Let us think of a situation in which the daily suicide rate along the synodic cycle varies widely. A chi squared goodness-of-fit test would reject the hypothesis of a constant daily suicide. However, were a lunar effect to exist, we would expect it to have a smooth effect: it just does not seem plausible that Days 9 and 11 of the synodic cycle are associated with above ave-

Figura 2: Observed daily rate of suicides and fitted cubic spline with  $\lambda$  chose by cross-validation.

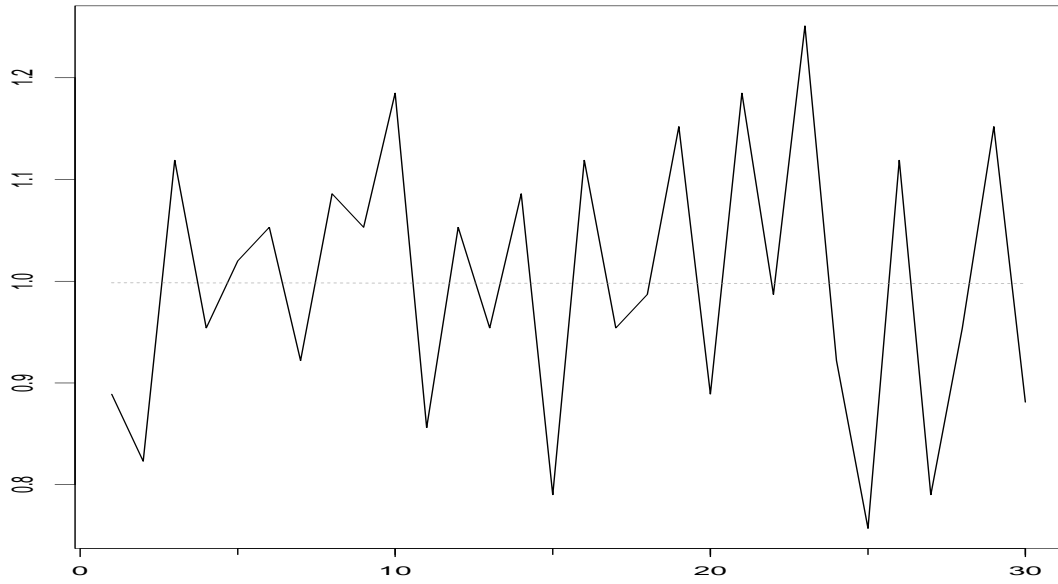
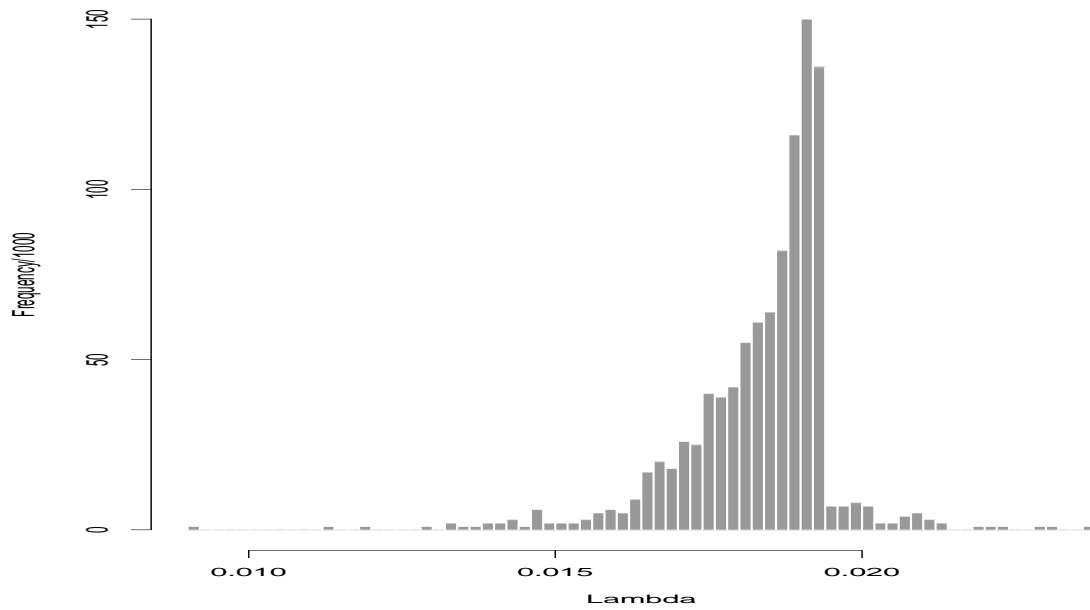


Figura 3: Histogram of values of  $\lambda_{CV}^{(k)}$  in one thousand random shufflings.

**Figure 3**  
**Histogram of frequencies of lambda**



rage daily suicide rates, while Day 10 is associated with below average suicide rates.

A chi squared test measures only departures of observed counts from expected counts, summarizing those departures in the statistic

$$Z^2 = \sum_{i=1}^n \frac{(O_i - E_i)^2}{E_i} \quad (3)$$

where  $O_i$  and  $E_i$  are respectively the observed and expected counts in cell  $i$ . No use whatsoever is made by the chi-square test of the natural ordering of the data.

The test we propose is an attempt to measure the complexity of the best fit. If no structure is present in the data, we can expect a straight line as the best fit — with a nearly constant value close to the mean of the data (such as we have found in the preceding Section). If there are patterns, the spline will capture them, its complexity will increase, and the  $\lambda_{CV}$  decrease. This is the basis of the proposed test, which therefore rejects the null hypothesis only when the alternative indicates more structure.

A chi squared test produced a  $p$  value of 0.9844; that is, the hypothesis of variation of the suicide rate along the synodic cycle is not rejected at the usual significance levels. If anything, the data looks *too much* in agreement with the hypothesis of a constant rate of suicide.

3. The proposed test is powerless to detect linear trends. A linear trend is a curve of "minimum complexity" and therefore indistinguishable (in terms of the value of  $\lambda_{CV}$ ) from the total absence of structure. It is clear, though, that a linear trend makes no sense in the case of the lunar cycle, as it would imply a discontinuity at the beginning of each cycle.
4. Why do people continue to believe in the moon's influence on strange or deviant behaviour in spite of the evidences against? [10] claim that tradition, folklore and popular misconceptions are the basis, efficiently spread out by the mass media. Individual experience may reinforce those perceptions, linking full moon and abnormal events in a cause-effect chain. This is most often related to cognitive biases like selective perception, selective exposure, self-fulfilling prophecy, etc.

We believe, in addition, that there is a body of specialists (physicians, nurses, policemen, social workers, criminologists, etc.) which, for the reasons enumerated above, maintain the wrong ideas. Because of their broad knowledge in their respective working areas and their close contact with the public, they disseminate distorted ideas which come to be seen as truth on account of the prestige of the professionals they emanate from.

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