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Research report

Seasonal changes in 24-h patterns of suicide rates: a study on train suicides in The Netherlands

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Abstract

Background: Annual patterns in suicide rates, peaking near the summer solstice, are well documented. It has been suggested that day length or total hours of sunshine has an impact on suicide rates. If these environmental factors are involved, we would expect changes in the daily pattern of suicide rates to occur over the year. To test this hypothesis, the 24-h patterns of suicide rate were investigated as a function of time of year. *Method:* Detailed information about the exact time of suicides in The Netherlands is only available for train suicides. Therefore, information concerning age, sex, time and place of occurrence of all verified train suicides over 15 years in The Netherlands ($n = 2830$) was obtained from The Netherlands Railways archives. *Results:* Daily patterns in train suicides show systematic variations of two kinds. First, independently of time of year, suicide rates at night drop to about 10% of their daytime values. Second, there are two daily peaks in the patterns which shift their timing over the year, with one peak occurring shortly after sunset, and the other one consistently occurring 9–10 h earlier. Both peaks shift with the 5.5-h shift in sunset time. *Limitations:* Train suicidal behaviour may not represent fatal suicidal behaviour in general. *Conclusions:* There are pronounced and systematic daily variations in train suicide rates in The Netherlands. One of these is related to clock time, the others are related to the light–dark cycle. The consistency of the patterns suggests a strong environmental influence on train suicidal behaviour. Research on 24-h patterns of suicide rates should control for time of year.

Keywords: Suicide; Seasons; Circadian rhythm; Railroads

1. Introduction

Seasonality of suicidal behaviour has been an object of study since the previous century. The observed peaks in suicide rates near the summer solstice have been a matter of interest and debate for over 150 years (Kevan, 1980; Aschoff, 1981; Massing and Angermeyer, 1985). It has been suggested that variations of psychosocial stress over time of day and season may account for some of the temporal variations in suicide rates (Durkheim,

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1897). More recently, the idea has been put forward of temporal variations in susceptibility to psychosocial stressors. This variation in susceptibility might be attributable to changes in central 5-HT (serotonin) neurotransmission (Maes et al., 1993). One argument in favour of this hypothesis is the observation of a significant temporal relationship between plasma L-tryptophan (a precursor of 5-HT) levels in healthy subjects and rates of violent suicide (Maes et al., 1995).

Whatever the mechanism by which the seasonal pattern of suicide rates is caused, there is a significant correlation between day length and suicide rate, and between hours of sunshine and suicide rate (Aschoff, 1981). If day length somehow would be causally involved in suicidal behaviour, it would be expected that the 24-h patterns of suicide rates would vary in the course of the year. Such circadian variations of suicidal behaviour (i.e., variations over the 24-h day) have received little attention. Uncertainty about the exact timing of many suicides complicates research in this field (Barraclough, 1976). Both Durkheim (1897) and Morselli (1882) noted that suicide is largely restricted to the daytime hours. These observations are confirmed by more recent major studies (Williams and Tansella, 1987; Maldonado and Kraus, 1991; O'Donnell and Farmer, 1994; Schmidtke, 1994) showing the lowest suicide rates between midnight and 06:00 h. However the temporal distribution outside this nocturnal period is unclear. Long intervals of three or more hours, chosen by most authors as the unit of temporal analysis, preclude a detailed analysis of 24-h patterns. Only two studies investigated the possible interaction between daily patterns of suicide rate and season (Schmidtke, 1994; Altamura et al., 1999). In the most recent study (Altamura et al., 1999) regarding different, but predominantly violent, types of suicide in Italy (39° N), no significant interactions were found between time of day of suicide and the quarters of the year. In the other study (Schmidtke, 1994), carried out in Germany (47°30′–54° N), the 24-h patterns of train suicide rates in the summer and winter season were compared. The peak of train suicides in males, was found to shift from 18:00–21:00 h in winter to 21:00–00:00 h in summer.

The present study focuses on train suicide as well. The advantage of investigating this type of suicide is that the exact moment of occurrence is known. Specific legal procedures connected with every train accident, i.e., collision with object, ensure detailed recording of circumstances and time. As a consequence train suicides are the best documented suicides in terms of time in The Netherlands and a number of other countries. In The Netherlands, train suicides accounted for 10–14% of all suicides in the period from 1980 to 1994. These percentages are higher than those reported in other European countries, like Germany and Austria, where they are 5.1 and 5.7 (Schmidtke, 1994; Deisenhammer et al., 1997), respectively. Still these percentages are small. Therefore it remains to be investigated whether the conclusions of the present study can be generalized to suicides in general.

Here, we specifically address the question of whether 24-h patterns of train suicide rates can be identified, and if so, whether they change with time of year. The results will be discussed in the context of possible environmental and biological factors that might be involved in processes underlying the suicidal behaviour under study.

2. Method

The Netherlands is a small, densely populated country with approximately 15 million inhabitants. It is located between 51 and 53°30′ N, in a temperate climate zone where the length of day varies considerably over the seasons. At this latitude sunrise varies from 08:46 h (Central European Time) in mid-winter to 05:18 h (Central European Summer Time) at the summer solstice. Sunset varies from 16:30 to 22:03 h. So the length of the day varies from 7 h and 44 min to 16 h and 45 min.

In the period studied, the railroads were managed by a single company, The Netherlands Railways, which entails a central registration of incidents. Total track length is 2800 km. With its 14.4 billion passenger-km in 1994, the railway net is one of the most intensively used in the world. Trains include long- and short-distance passenger trains and freight trains. City transportation, like tram and subway systems, has not been included in this study. Information about passenger and freight train traffic intensities was obtained from the traffic control centre of The Netherlands Railways. Seasonal variation in train traffic intensity was negligible. Train traffic intensity is stable during weekdays and drops to 87 and 76% of weekday values on Saturday and Sunday, respectively. Train traffic intensity over the 24-h day, as investigated on five different locations shows a sharp increase after 06:00 h and a sharp decrease after midnight. Between these hours train traffic intensity shows a bimodal pattern with a dip at noon and rush-hour peaks at 08:00–09:00 and 17:00–18:00 h. Train traffic between 02:00 and 05:00 h exclusively consists of freight trains and is reduced to 10% of daytime values.

Throughout the years 1980–1994, relevant demographic data on suicides and suicide attempts were obtained from the archives of the Department of Corporate Communications of The Netherlands Railways. This department keeps records of all railway incidents (accidents and suicides) based on information supplied by the local police. By law, the local police and the local coroner investigate every unnatural death in The Netherlands. The archives contain 2830 cases of suicide recorded during the 15-year period of the study (m/f = 1788/1027, gender unknown = 15) (mean age of men = 39.3 years (S.D. = 16.4, median 35 years), mean age of women = 40.1 years (S.D. 14.4, median 39 years) (Mann–Whitney test statistic = − 2.7; $P = 0.006$)), as well as 254 suicide attempts, i.e., train contact without fatal outcome (m/f = 137/116, gender unknown = 1). As the mechanisms underlying nonfatal suicidal behaviour may differ from those underlying suicides (Jessen et al., 1999), nonfatal cases were excluded from the study. The total number of suicides ($n = 2830$) includes 76 cases which were initially registered as 'probable cases' of suicide. We decided to include these cases as confirmed suicides on the basis of additional documentation, like letters from relatives and/or railway police reports kept in the archives of The Netherlands Railways. The date at which suicide occurred was known in all 2830 cases, but the exact time was missing in 237 cases. Given the fact that less than 2% of trains in The Netherlands are delayed by more than 15 min, the time at which the event took place could be estimated from timetables in 136 of these cases. In the remaining 101 cases (3.6%) insufficient information was available to deduce a likely time of occurrence. These cases were excluded in all analyses regarding time of day.

In order to arrive at both a sufficient temporal resolution and a sufficiently large number of cases in each interval, we chose to divide the year into thirteen, 4-week intervals. The advantage of using an integer number of weeks instead of using, for instance, conventional months is that systematic fluctuations in the course of a week will not lead to sampling artefacts. In accordance with other studies (Massing and Angermeyer, 1985; Schmidtke, 1994) we found in our data a maximum of suicides at the beginning of the working week and a minimum on Sunday: 437, 437, 406, 413, 400, 395, 342, Monday through Sunday, respectively, (all cases over 15 years) ($\chi^2 = 15.3$; df = 6; $P = 0.02$). As weekends have systematically fewer cases than weekdays, the monthly values depend on whether a particular month contains four or five weekends. As a consequence of our procedure of dividing, the suicides on days 365 and 366 of the year (12 cases) were not included in the analyses regarding time of year. Poisson regression analysis was used to verify whether the 4-week values did differ.

We chose three different approaches for our study of 24-h patterns of suicide rates. First, in order to obtain an overall 24-h profile with a high temporal resolution, suicide rate as a function of clock time was analysed in half-hour intervals. Second, the amounts of time between event and sunrise and between event and sunset were calculated for each suicide. These amounts were also classified in half-hour intervals in order to obtain a detailed description of the timing of suicides relative to sunrise and sunset. Third, we defined cells on the basis of each of the 24-clock hours in each of the thirteen, 4-week intervals and counted the numbers of suicides that occurred in each cell. In this way a two-dimensional picture emerges in which suicide rate is indicated as a function of the time of day *and* as a function of the time of year simultaneously. In addition, we chose to plot the two-dimensional function by attributing colours to the function values. It should be noted that the number of two-dimensional cells in the colour plots amounts to $13 \times 24 = 312$. As a consequence, the numbers of cases per cell are small with an average of 8.7 in all category cases. In order to reduce the influence of chance fluctuations on the results, we smoothed the data in the following way. The value of each cell was replaced by a weighted average of its own value and the values of the eight cells surrounding it. The relative weight of the surrounding cells was set to 0.5 in this smoothing procedure.

Statistical analysis of the 24-h patterns over the seasons was performed with Poisson regression analysis. A full model was specified for the purpose of this analysis, containing time of day, time of year, gender, 24-h variation in train traffic intensity, as well as terms for interactions between time of day and time of year, and time of day and gender. Age was not included in the model. Time of day was defined by four, 6-h periods: 00:00–05:59, 06:00–11:59, 12.00–17:59 and 18:00–23:59 h; time of year was defined as a winter season consisting of the 4-week intervals 11–13 and 1–3 and a summer season consisting of the intervals 4–10. The model was weighted for the difference in duration of the seasons.

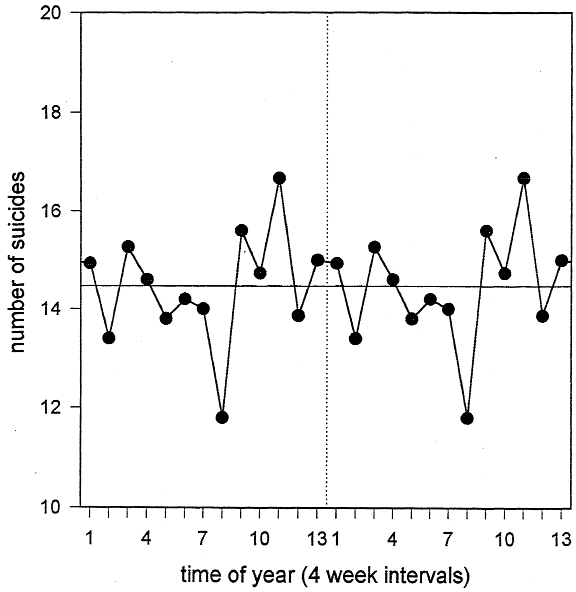

Fig. 1. Total number of train suicides in 4-week intervals, as a function of time of year. Data are double plotted to emphasize possible temporal patterns.

3. Results

The annual pattern of train suicides in The Netherlands, accumulated over 15 years, is presented in Fig. 1. Averaging the results and dividing this by 15 yields a mean of 14.5 cases per 4 weeks. Obviously, the data do not show the expected peak near the summer solstice. Poisson regression analysis indicates that there is no significant time trend across the months of the year ($\chi^2 = 17$; df $= 11$; $P = 0.11$).

When we analyse the same data relative to clock time, a pronounced 24-h pattern emerges (Fig. 2). Half-hourly values are about 10 times higher between 10:00 h and midnight when compared to the interval between 02:00 and 06:00 h. Sharp transitions separate these two relatively constant levels.

In view of the finding that train suicide rates in The Netherlands do not show a very pronounced seasonal pattern (Fig. 1), and that train suicide rates are more or less constant over the daytime hours (Fig. 2), it is quite surprising to find a strong temporal relationship between suicide rates and

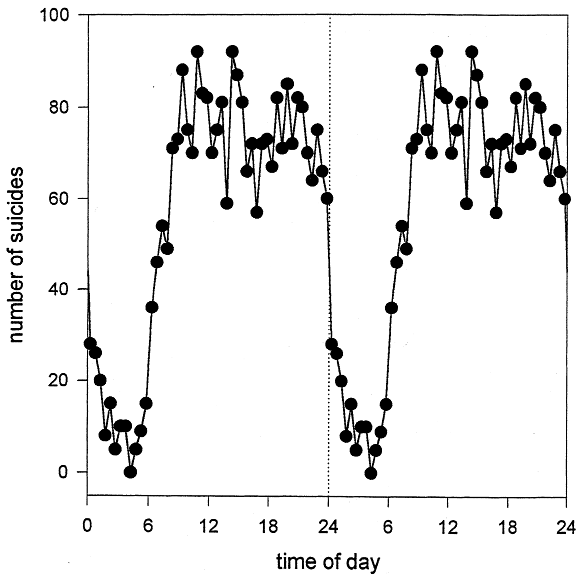

Fig. 2. Number of train suicides per half hour over the day as a function of clock time, double plotted. Accumulated values over 15 years.

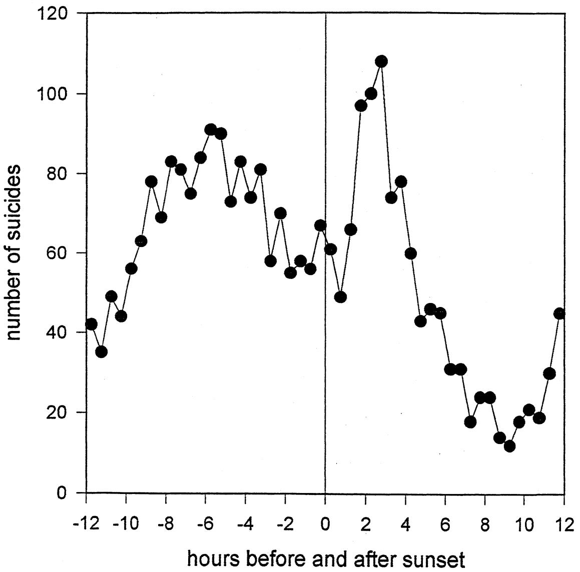

Fig. 3. Number of train suicides per half hour relative to the time of sunset. Accumulated values over 15 years.

timing of sunset (Fig. 3). There is an increase of about 80% in suicide rates starting at about 1.5–2 h after sunset. In the 4 h before sunset, prior to the sudden increase, values are systematically lower than earlier in the day.

The analysis of suicide rates relative to sunrise (data not shown) shows a gradual increase in the morning hours.

The sudden increase in suicide rate shortly after sunset confirmed our expectation that it is appropriate to further examine the data as a function of time of day and as a function of time of year simultaneously. Fig. 4a presents the results, coded in colour. The number of suicides ranges from blue, which means very few cases, to light green which corresponds to many cases. 'Many' is used here in a relative sense, because the large number of cells drastically reduces the number of cases per interval. For that reason the actual data have been smoothed slightly, as explained in the methods section. The data are plotted as a function of clock time (horizontal axis, interval width is 1 h) and as a function of time of year (vertical axis, interval width is 4 weeks). The data are double plotted along both axes in order to get a better picture of the pattern. The times of sunrise and sunset throughout the year are indicated with the black curvilinear lines. The discontinuities in these lines are due to shifts to and from summer saving time.

Several patterns emerge from Fig. 4a. First, there is a clear reduction in suicide rate during the night. Given the straight vertical arrangement of this phenomenon in the figure it would seem plausible to link this phenomenon to clock time (Fig. 2) and to interpret this phenomenon as being related to sleep and/or to the intensity of train traffic, which at night, between 02:00 and 05:00 h, is reduced to 10% of daytime values.

Second, the mentioned increase in suicide rates after sunset (Fig. 3) is visible as an oscillating band of predominantly light green, yellow and orange values, parallel to the black line of the sunset times, illustrating that the suicide rates are linked to sunset throughout the year.

Third, there is a second, as yet unexpected, oscillating band of light green, yellow and orange values in the data. Peak values systematically occur some 9–10 h before the evening peak, leading to a daytime maximum of suicide rate at about 09:00 or 10:00 h in winter and 14:00 or 15:00 h in summer.

Application of Poisson regression analysis showed that season altered the relationship between suicide intensity and time of day in a significant way ($\chi^2 = 8.3$; df $= 3$; $P = 0.04$). In addition it showed that the effect of gender also differs in terms of suicide intensity with time of day ($\chi^2 = 22.6$; df $= 3$; $P < 0.001$). Therefore, in the figures, results are presented for the male and female datasets separately. While there is a relative preponderance of evening suicides in men, and of daytime suicides in women, the three described aspects of Fig. 4a are also present in the separate male and female data sets (Fig. 4b,c) although it must be mentioned that the interactions between season and time of day are no longer significant for these smaller subsets of the data, $\chi^2 = 4.2$; df $= 3$; $P = 0.245$ (men), $\chi^2 = 5.2$; df $= 3$; $P = 0.16$ (women).

4. Discussion

In spite of the fact that the data on train suicides in The Netherlands, collected over 15 years, do not demonstrate a pronounced seasonal dependence

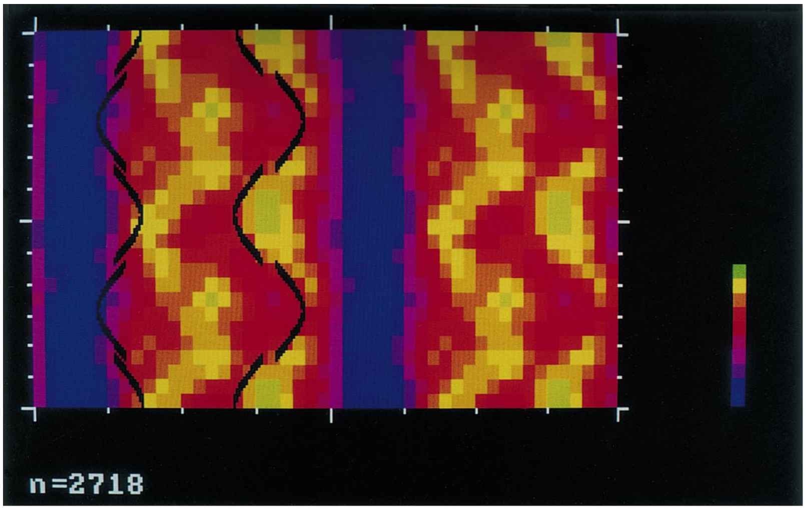

Fig.4a

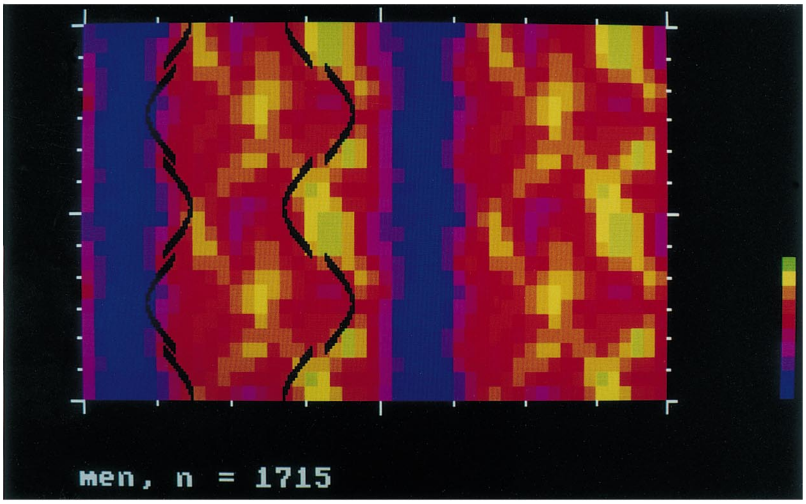

Fig.4b

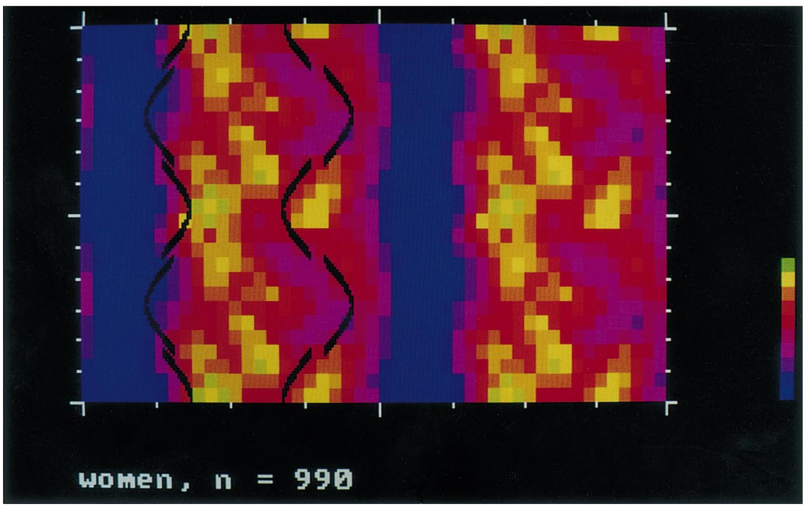

Fig.4c

when plotted as a function of time of year, nor show a pronounced diurnal pattern when plotted as a function of clock time, the data do reveal a strong and significant seasonal modulation of diurnal suicide patterns when plotted two-dimensionally. The diurnal distribution changes over the year in such a way, that peaks in summer occur at clock times at which there are troughs in winter and vice versa. This pattern is quite impressive and robust as demonstrated by the fact that the effect of season on 24-h patterns is visible in both men and women separately.

As is the case with official suicide statistics, there is the possibility that this study includes false-positive cases, i.e., accidents labelled as suicides, and that true suicides were erroneously considered as accidents, leading to false-negative cases. However, there is no reason to suspect that this would bias the results with respect to the time of the event in terms of date and/or clock time in a significant way.

The data are partly consistent with earlier findings regarding train suicide rates by Schmidtke (1994) who noted a seasonal shift of evening peak values in men, but not in women. In our study, evening peak values shift with the seasons, both in men and women. It is not clear what causes the discrepancy between the results in females in our study and the study by Schmidtke (1994). In both studies a preponderance is noted of female suicides at daytime versus male suicides in the evening. Social factors might explain these differences.

The negative findings of Altamura et al. (1999), regarding a seasonal change in 24-h patterns of suicide rate, could be due to the relatively small number of cases ($n = 355$).

Some of the patterns in the temporal distribution of train suicides have plausible explanations. The nocturnal trough, which is strongly linked with clock time, is most likely related to sleep. This is consistent with the existing literature (Durkheim, 1897; Williams and Tansella, 1987; Maldonado and Kraus, 1991; Schmidtke, 1994). The finding that the ratio of nocturnal and diurnal values in this study is much smaller (1/10) than the ratio of 1/3 observed in a study regarding all types of suicides (Williams and Tansella, 1987) and the fact that the magnitude of the nocturnal drop in this study matches the 90% reduction of train traffic at night suggest that nocturnal train traffic reduction or the general notion about this reduction in the population, plays an additional role.

The evening peak in suicide rate may have a psychosocial explanation. In The Netherlands dusk, i.e., civil twilight, lasts between 1 and 2 h. A subset of suicide victims, may wait until complete darkness, in order to be less visible to passers-by and traindrivers and to maximize the chance of uninterrupted completion.

The most intriguing finding is the morning/midday peak which shifts its timing with the seasons. Given our interpretation of the evening peak, a relative decrease in suicide rate in the hours prior to the evening peak is to be expected. This could explain why the midday peak declines later in summer than in winter. However, it is difficult to understand why the rise of the daytime peak moves towards the afternoon in summer and moves back to early morning in winter.

Other simple explanations are not very likely either. Could it be that the 24-h rhythm of serotonin is involved? There is ample evidence that serotonin neurotransmission is involved in violent suicides (Lester, 1995). In addition, seasonal variations in a variety of serotonergic parameters have been found (Brewerton, 1989). In one study reporting on hypothalamic 5-HT (serotonin) levels in post mortem brain tissue, it was found that 5-HT levels between 06:00 and 15:00 h and between 15:00 and 06:00 h differ in the periods December–May and June–November (Carlsson et al., 1980). Apart from this scanty information about the simultaneous influence of season and time of day on 5-HT function in humans, we have found no further data that might be relevant in this context. Moreover, it does not seem very likely that seasonal changes in biological rhythms, responsible for circadian variation in 5-HT function and/or in other parameters, could explain our results. The difference in the phase position of

Fig. 4. Mean values of train suicides per hour *and* 4-week period, double plotted along both axes. The colours blue and light green represent minimum (= 0) and maximum values, respectively. (a) All cases; (b) men; and (c) women.

the circadian system between summer and winter is about 1.5 h in healthy subjects, with a later phase position in winter (Honma et al., 1992; Laakso et al., 1994). This difference is definitely insufficient to explain an approximate 5-h shift of peak incidence of suicides in the opposite direction!

In the absence of relevant human data, it is of interest to refer to recent animal data, which showed the existence of circadian and circannual rhythms in the central 5-HT function in rats living in a 12-h light–12-h dark cycle. The responsiveness to a selective 5-HT_{1A} agonist showed a 6–8.5-h shift, both ways, over a 1-year period (Nagayama and Lu, 1998). Demonstration of shifts in 5-HT function of similar magnitudes in man, would then, in view of our findings, support the 5-HT hypothesis regarding violent suicides.

Since no information on prior psychiatric symptomatology is available from The Netherlands Railway archives, it is not possible to link the observed patterns to specific diagnostic groups, which might give possible clues to further unravel the background of this intriguing phenomenon.

It is also difficult to understand our findings in terms of fluctuations in intensity of social life as was suggested by Durkheim (1897) to explain 24-h and seasonal patterns: the shifting peaks do not show any temporal relationship with meal- and worktimes.

In contrast to our expectations, train suicide rates did not show any significant annual fluctuations. However, our observation of the two peaks shifting with the seasons and the nightly trough might provide an explanation for the absence of a peak near the summer solstice in our data. Early summer peaks are virtually always reported in the larger studies on suicide epidemiology, although the amplitude of the peak would seem to depend on latitude and would seem to be decreasing in the course of this century (Aschoff, 1981). If we accept the interpretation that a subset of individuals shows a preference for the first dark hours of the night for their act, these subjects will not have much opportunity in early summer when sunset is at about 20:00 h. If these persons were to choose for another method, their choice would suppress the early summer peak in train suicides.

Irrespective of the significance of the summer solstice peak in suicide rate, the present study has revealed pronounced daily patterns, which suggests a strong influence of environmental and/or biological factors on train suicidal behaviour.

In the context of these findings it is of great interest to obtain an equally detailed picture of temporal patterns of other types of suicide. Replicating the present type of analysis with other types of suicide might show patterns which have remained undetected in previous approaches in which time of day and time of year were studied independently. This, in its turn, might generate new ideas with respect to the determinants of suicidal behaviour.

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