Meteorological factors and seasonality in suicidal behaviour in Denmark 1970-2000

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ABSTRACT

The aim of the present study was to investigate the influence of meteorological factors on suicidal behaviour, and examine if this influence was affected by season and month. Danish data on suicidal deaths 1970-1998 (n = 35.680) and attempted suicides 1989-2000 in the County of Funen (n = 9.020) were analysed statistically. An association between specific meteorological variables and suicidal behaviour was found and discussed, in that meteorological factors seem to have an impact on suicidal behaviour. The importance of several meteorological factors varied with season and month. A day to day change in meteorological factors seems in general to reduce the risk of suicidal behaviour. Identifying rhythmic patterns in suicidal behaviour may have implications for understanding the aetiology of suicide and for planning and staffing prevention and support services.

1. Introduction

The Waste Land: I. The Burial of the Dead

"April is the cruellest month, breeding
Lilacs out of the dead land, mixing
Memory and desire, stirring
Dull roots with spring rain.
Winter kept us warm, covering
Earth in forgetful snow, feeding
A little life with dried tubers."

T.S. Eliot

Numerous epidemiological studies have shown the effect of cyclic patterns, such as the time of year, day of the week, or time of day, on psychological conditions. Hippocrates (400 BC) was one of the first to recognize the existence of seasonal rhythms in mental and physical health:

"Whoever wishes to investigate medicine properly should proceed thus: In the first place to consider the seasons of the year and what effect each of them produces" (cited by Hare, 1975).

In the late 1800s, Durkheim documented that also suicidal deaths have a seasonal variation, with a peak in late spring or early summer and a trough in winter. The spring peak in suicides has since, despite great variations in geographical locality and the timing of studies, not to mention socio-cultural diversity, been a well-documented phenomenon in e.g. Denmark (Jessen et al., 1998), Finland (Näyhä, 1982; 1983), UK (Meares et al., 1981), Italy (Micciolo et al., 1989; 1991; Preti, 1997), Greece (Bazas et al., 1979), and the USA (Lester, 1971; Lester & Frank, 1988). The suicide periodicity seems to be ubiquitous, since also southern hemisphere countries like Australia (Eastwood & Peacocke, 1976; Parker & Walter, 1982),

South Africa (Flisher et al., 1997), and Chile (Trucco, 1977; Retamal & Humphreys, 1998) display a similar seasonal pattern, although the seasons there are 'reversed' compared to the northern hemisphere because spring occurs from September to November.

It has been speculated that the crucial factors in the relationship between seasons and suicidal behaviour are weather conditions. Many different kinds of meteorological factors have been thought to exert a more or less direct influence on the suicide rate (cf. Hakko, 2000, for a review). One of the first climatic theories was presented by Montesquieu 1748 in his book *De l'Esprit des Lois*, wherein he stated that foggy, dull or changeable weather make the human mind prone to melancholy and suicide. Later, in the 1880s, Italian statisticians Ferri and Morselli observed that climatic changes might cause changes in biological processes. Morselli (1881[1879]) conducted and published the first comprehensive comparative study of the monthly distribution of suicide, in that he evaluated data from 18 European countries and found suicide spring peaks in 17 of them. He suggested that meteorological factors, particularly temperature changes in spring and early summer, influenced the organism not yet acclimatized and, thus, played important roles as contributing factors in suicide seasonality. In his famous study *Le Suicide*, Durkheim (1951[1897]) criticised this view for lacking empirical basis. Durkheim observed that there is a perfect continuity of the suicide curve, increasing from winter to summer, which discredits the theory of weather fluctuations as the cause. Instead he identified the *length of day* as the crucial factor, because it has an impact on the intensity of communal life and social activity.

As Hakko (2000) recently has noted, a statistical analysis, which intend to prove a seasonal pattern in suicide rates, is mostly of academic interest, unless the reasons for causing the pattern are investigated. To determine which elements play a possible role in the seasonality

of suicides, Chew & McClary (1995) divided the explanations for seasonal patterns and trends into two categories: sociodemographic and bio-climatic.[1]

The sociodemographic hypothesis:

Suicide seasonality co-varies with the intensity of social activity

The sociodemographic hypothesis is based on the theory of seasonal fluctuations in the social interaction and relational habits of individuals: in warmer months social intercourse is far more frequent than in cooler months. The increase of social activity in spring and summer months may provoke self-destructive actions due to increased exposure to conflicts and frustrations (Lester, 1995), or, as Durkheim indicated, when social activity in a community increases, those who are isolated and lonely are more disposed to be confronted with their predicament and subsequently suffer from suicidal ideation. The energy and vitality which other people exhibit in spring might be considered a provocation in the mind of the suicidal person. The effect of seasonal climate variations on social activity could thus indirectly influence the individual's disposition to develop a depressive episode or have an impact on how the individual copes with psychological stress, such as negative life-events, socio-economic problems or the presence of physical illness (Preti, 1997). In other words, variations of psychosocial stress over time of season may account for some of the variations in suicide rates.

[1] We prefer to use the term bio-meteorological. In seasonality studies the terms 'climate' and 'weather' have often been used as synonyms, but it should be noted, however, that whereas the term 'climate' describes relatively stabile spatial variations in meteorological conditions, the term 'weather' is normally referring to the momentary variations in meteorological conditions (Rotton, 1986). While weather factors include a set of specific conditions of the atmosphere at a specific time and place (e.g. ambient temperature), climatic factors signifies the synthesis of weather conditions over time (e.g. temperate climate) (Hakko, 2000).

The bio-meteorological hypothesis:

Suicide seasonality co-varies with meteorological factors

The bio-meteorological hypothesis, promulgated by the Italian school in the late 1800s, is concerned with factors, which may affect the circannual rhytms in specific biochemical processes associated with susceptibility to psychosocial stressors (Flisher et al, 1997). Seasonal variation in melatonin metabolism (Petridou et al., 2002), dopamine (Skutsch, 1983), and particularly hypothalamic 5-HT (serotonin) neurotransmission related functions may be involved here (Brewerton, 1991; Maes et al., 1993*b*). Thus, the seasonality of suicide seems to be associated with the seasonality of severe mood disorders, since the presence of such disorders increase the risk of suicide. Seasonal occurrence and recurrence in depressive and manic disorders has been stated by several authors (Wehr & Rosenthal, 1989; Faedda et al., 1993; Sayer et al., 1991). The systematic findings in studies of seasonal variations in the incidence of suicide and depression have led to the definition of a new nosological entity, the so-called "seasonal affective disorder" (SAD) (Rosenthal et al., 1984), describing a bipolar condition characterized by annually recurrent depressive episodes. It has been suggested that the annual rhythm in human biological processes, which underlie a changing susceptibility to e.g. depression, may be influenced by meteorology. The observed seasonal asymmetry in suicidal deaths suggests a relationship between variations in specific meteorological factors, such as amount of light, and systems that control circadian rhythms and those that control mood. Although the recurrence of some affective disorders seems to follow a seasonal pattern, there is, however, a general lack of studies of either the prevalence of SAD among suicide victims or the incidence of suicides among patients with SAD (Hakko, 2000).

The psychosocial hypothesis:

Suicide seasonality co-varies with the "broken promise effect"

In addition to these hypotheses, we find it useful to add a third: the psychosocial hypothesis, proposed by Gabennesch (1988), which states that a severely depressed, suicidal person may be negatively influenced by spring because it is the time most people associate with new beginnings. Spring is not merely a time of nicer weather, but positively connoted with youth, vitality and on a deeper level symbolically experienced as a psychological renewal (Massing & Angermeyer, 1985). Thinking of spring tends to stimulate hope or promote elevated positive expectations in suicidal persons that if they can hold on in winter until the arrival of spring, they will actually feel better or be relieved of their social isolation and emotional distress (Lester & Frank, 1988). According to Gabennesch (1988), the problem occurs when, despite the new season, matters remain unchanged in the life circumstances of the seriously depressed person. It seems as if a promise has been broken. The broken promise can be detrimental to psychological well-being, because the unmet expectations may lead to a greater sense of deprivation in the despondent individual, when he or she fails to find any psychological relief at these times. The person sinks further into hopelessness, falling below the suicide threshold, impelling him or her to take action.

Most of the variables which has been shown or speculated to influence suicidal behaviour can be analytically divided into these three major modes of thought. It is worth noticing that we do not consider the three theories to be mutually exclusive. We are, however, particularly interested in the socio-cultural forces, which operate on the meteorological variables that precipitate suicidal behaviour. We are fully aware of the fact that strictly psychosocial or socio-demographic explanations may be insufficient to explain suicide seasonality – since it is not possible to rule out seasonal recurrence of mental disorders (involving suicidal ideation)

in the aetiology of suicide – but in the search for the underlying dynamics to the enigmatic phenomenon, we intend to use the psychosocial and the socio-demographic theories, because we find these explanations most promising in helping to make sense of the data.

Many of the previous studies on the contribution of climate and meteorology to suicide rates have been based on data from many different nations, thus neglecting to take the different social structures and cultural habits into consideration. Ellner (1977) and Rotton (1986) observed highest suicide rates in nations with colder climates, but failed to realize that such nations also tend to be more heavily industrialized than countries with warm climate (Preti, 1998). Because of this, we find it appropriate to work with data from a single nation in order to differentiate the effects of climate and meteorology on suicidal behaviour from those arising from social and cultural influences.

2. Material and method

Denmark has approximately 5.3 million inhabitants, forming a fairly homogeneous population in regard to social and cultural factors which may influence suicidal behaviour. Due to its northern geographical location (between latitudes 54° and 58°41' N), in a temperate climate zone, with a clear demarcation between various seasons and a considerable seasonal variation in the length of day, Denmark is an ideal locus for studying the effects of seasonal phenomena.

The analysis is based on suicidal deaths in Denmark in the period 1970 to 1998 (n = 35.680; males = 22.787; females = 12.893; age 15+), and attempted suicides in the county of Funen from April 1st 1989 to 31st December 2000 (n = 9020; males = 3986; females = 5034; age 15+), as recorded in the Danish Suicide Register. The divergence in time period between completed and attempted suicides is due to the fact that the frequency of attempted suicides

have only been systematically registered since 1989, when a monitoring project was initiated in cooperation with WHO/Euro: "Multicenter Study on Parasuicide". The County of Funen is thought of as representative for the whole country (approx. 10% of Denmark in size and population).

Meteorological data

The information on daily weather conditions was obtained from the Danish Meteorological Institute for a 30-year period. The meteorological data is based on daily observations from Odense Airport and the nearby meteorological office in Bellinge, Aarslev[2], as to the following weather variables: minimum and maximum temperature (°C), precipitation (mm of equivalents of water), sunshine minutes and snow-covering (more than 50 % covering). Furthermore, every three hours observations on wind direction (°), wind velocity (m/s), visibility (km), cloudiness (eight parts), air pressure (hPa), air temperature (°C), relative humidity (%) and a special coded weather type (like type of precipitation, thunder and lightning etc.) were recorded. Three-hour observations were converted into daily observations by calculation of mean, maximum and minimum values (temperature, wind speed, visibility, cloud cover, air pressure, and relative humidity). The magnitude of changes (but not the direction) for a meteorological factor during the day was estimated using standard deviation of all three-hour observations for that day. A day was defined as the time from 6.00 UTC[3] to 6 UTC the following day.

[2] For obvious reasons the applicability of meteorological data becomes more questionable as the geographical size of a country increases. By restricting the study to Denmark, a small country with relatively homogeneous climate and weather conditions, we find it reasonable to assume that all suicides in Denmark can be analyzed on the basis of meteorological data from Funen.

[3] UTC (Coordinated Universal Time). 6 UTC corresponds to 7.00 AM local time (8.00 AM in periods with Daylight Saving Time)

Daily observations included maximum and minimum temperature, minutes of sunlight, and snow cover higher than 50% (a dichotomous variable).

Relative meteorological factors

The study is mainly based on relative meteorological parameters, i.e. relative to parameters expected for the season. Denmark has a temperate climate, which means that especially temperature, but in fact all meteorological factors vary considerably during the year. The expected values of meteorological factors were calculated from a 30-year period (1970-1999).

The observed values of meteorological factors were divided into categories using percentiles. For most meteorological factors three categories delimited by 25- and 75-percentiles were calculated, except for temperatures (7 categories, delimited by 10-, 25-, 40-, 60-, 75-, and 90-percentiles). The percentiles were smoothed by a five-week moving average. Observed values of meteorological factors were categorized as discrete factors by comparison to expected categories (3 discrete factors for amount of sunlight, wind speed, visibility, cloud cover, air pressure, and relative humidity and 7 discrete factors for temperature). Each discrete factor was considered a binary factor and subject of a statistical analysis.

Absolute meteorological factors

Precipitation was categorized as type (dry, snow or rain) and amount less than 1 mm, 1 to 5 mm, 6-15 mm, and more than 15 mm.

For each meteorological factor standard deviation was used as a measure of change during the day. Smaller changes were defined as less than the 50-percentile.

Change in weather from one day to another

A weather factor that changed from one category to another was compared to weather factors not changing.

Statistical analysis

In the pilot-study (Jessen et al., 1998), a combination of time series analysis and linear regression were used on all weather variables. Based on the findings it was concluded that specific weather factors did have an influence on suicidal behaviour, but that at the same time more sophisticated and advanced statistical methods were needed in the further investigation. All dichotomous weather factors were subject to a statistical analysis based on a conditional Poisson distribution (see appendix). In the analysis results were corrected for year, month and day of the week, so no trends of any kind longer than one month have any influence on the results. The analysis of a weather factor does not necessarily include all days in the period. Long periods of constant weather, like severe droughts, were not included, as well as weather factors typical of specific seasons, like snow cover, only included winter days.

3. Results

In order to investigate a possible association between suicides and various meteorological factors, we collected data from the Danish Meteorological Institute as to several weather variables, such as humidity, duration of sunlight and ambient temperature. Our results are displayed in table 1.

Table 1. Suicide and weather factors. percentage deviation from expected and significance (Bold: significance < 0.01)

Fewer suicides

Weather factor	Pct. dev.	significance
Danger of frost-bite	-24.9	0.0492
Drifting snow part of the day	-17.3	0.0194

Day-frost	**-6.5**	**0.0007**
Snow-cover	**-5.3**	**0.0025**
Very low temperature	**-5.2**	**0.0000**
Very low min. temperature	**-4.8**	**0.0005**
Very low mean temperature	**-4.7**	**0.0005**
Very low max. temperature	**-4.3**	**0.0013**
(Very) low min. temperature	**-3.5**	**0.0000**
Snowfall	-3.4	0.0287
(Very) low max. temperature	**-3.1**	**0.0001**
5-15 mm rainfall	-2.9	0.0329
5-15 mm precipitation	-2.9	0.0270
(Very) low mean temperature	**-2.7**	**0.0008**
(Very) low temperature	**-2.7**	**0.0004**
Low min. temperature	-2.5	0.0256
Normal abs. mean humidity	-1.2	0.0137

More suicides

Weather factor	Pct. dev.	significance
"Tropical night"	**42.2**	**0.0079**
Summer day (max. temperature>=25)	4.8	0.0266
Very high max. temperature	**4.0**	**0.0038**
Very high mean temperature	**3.6**	**0.0091**
Dry air (abs. mean humidity)	**3.2**	**0.0008**
Very high temperature	3.1	0.0123
No snow-cover	**3.0**	**0.0015**
(Very) low (max. temperature)	**2.7**	**0.0009**
Nordic summer day (>=20)	**2.6**	**0.0064**
Fairly low (min. temperature)	2.5	0.0230
(Very) high (temperature)	**2.2**	**0.0060**
(Very) high (mean temperature)	2.0	0.0136
(Very) high (min. temperature)	1.9	0.0205
No danger of frost-bite	1.4	0.0453

In table 1 is shown the meteorological variables which are statistical significant at the 5 % level. These factors vary widely in Denmark, because of the pronounced differences between the seasons. The highlighted factors are meteorological variables which are significantly ($p<0.01$) associated with increased or decreased suicide rate. Especially, tropical nights ($p = 0.0079$), high maximum temperature ($p = 0.0038$) and dry air ($p = 0.0008$) are positively correlated with an increase in the incidence of suicide. Conversely, e.g. snow-covering ($p = 0.0025$) and low minimum temperature ($p = 0.0005$) are associated with fewer suicides. The

results generally suggest a significant positive correlation between warm weather and increased number of suicides (predominantly higher suicide rate than expected), whereas cold weather reduces number of deaths by suicide (predominantly lower suicide rate than expected), as can be seen in figures 1 and 2 and in table 2.

Figure 1: The influence of cold weather on suicide, monthly distribution. Percentage deviation from expected

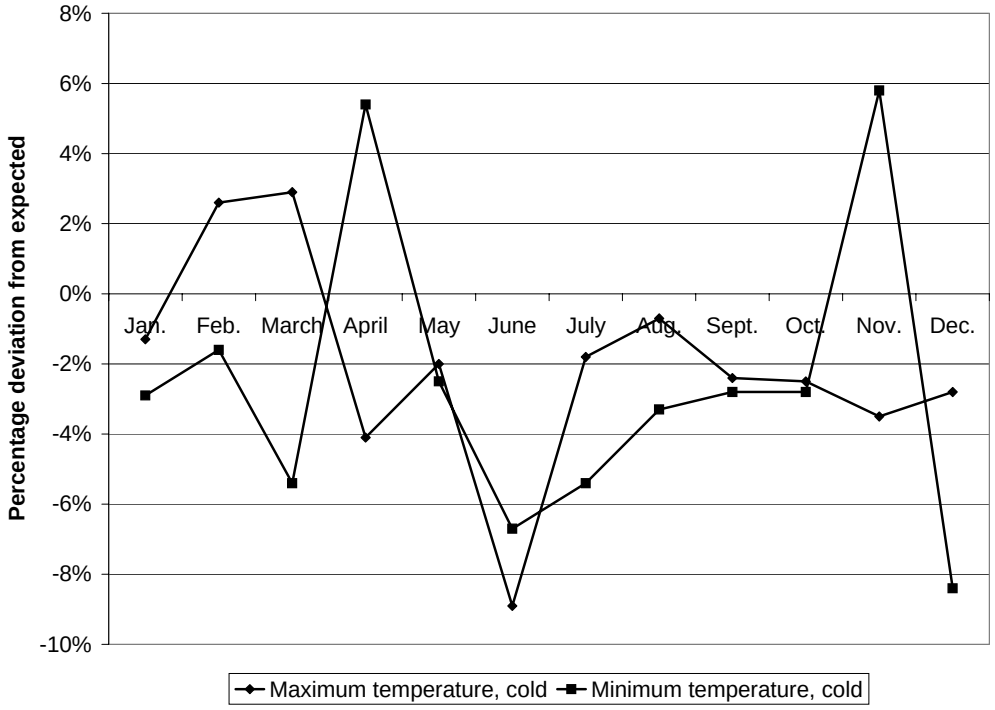

Figure 2. The influence of warm weather on suicide, monthly distribution. Percentage deviation from expected

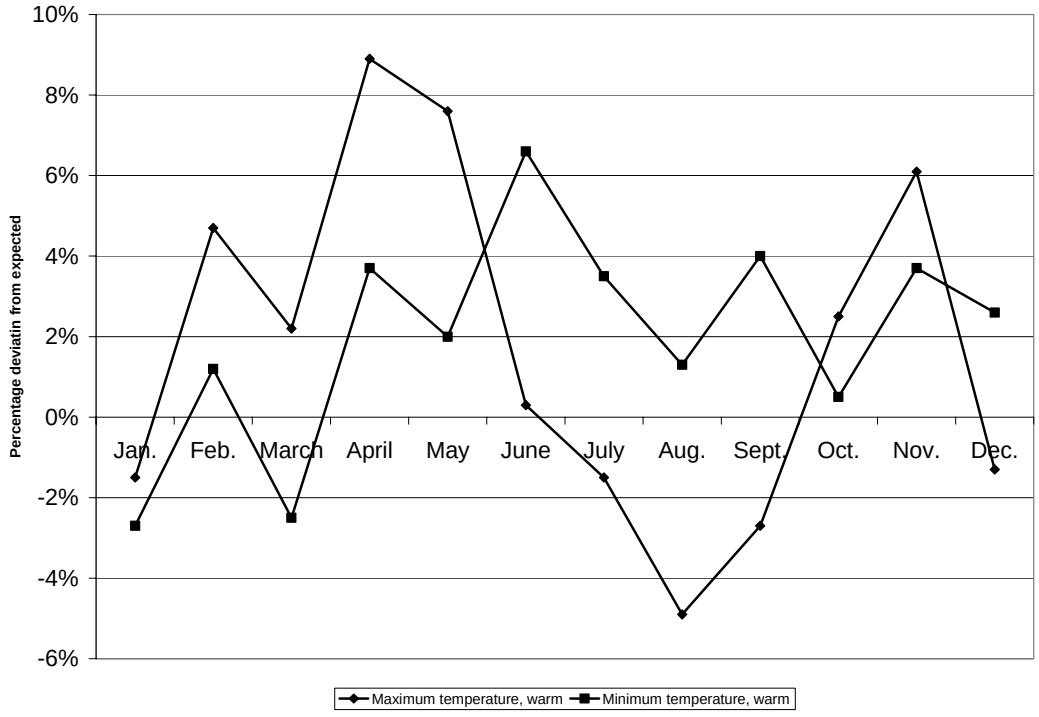

Table 2. Suicide and weather factors by month. percentage deviation from expected and significance (Bold: significance < 0.001) See below

The data in table 2 suggests that several meteorological factors, e.g. fog ($p = 0.0025$) and high level of humidity ($p = 0.0021$) in autumn, are positively associated with increased suicide risk, even though the relationships are rather weak. The suicide incidence increases on bright days in the summer time. In regard to weather changes, it is worth noticing that a sudden change in weather may be considered a protection against suicidal behaviour, unless it is a change to cold weather or from very hot or dry weather. The relationship between weather changes and suicide is presented in table 3.

We conducted the same analysis on attempted suicides, but the results turned out somewhat unclear. The same tendencies as in suicides were present, but far less significant.

4. Discussion

Previous studies on the relationship between meteorological factors and suicide rates have yielded inconclusive. Although several studies failed to find any significant link between suicide and a number of meteorological variables (Micciolo et al., 1988; Dixon & Shulman, 1983, Pokorny et al., 1963), numerous studies have detected an apparent positive correlation between elevated suicide rate and specific weather variables, such as higher temperature, increased daylight duration, increased sunshine hours, or decreased levels of humidity (Preti, 1998; Souêtre et al., 1987, Maes et al., 1994). Salib & Gray (1997) found suicides to be related to fine weather conditions, and not to extreme weather conditions, as reported by some authors (Wang et al., 1997). In Italy (Preti, 1998), a positive correlation was found between mean monthly distribution of suicides and indicators of sunlight exposure and the mean monthly values of maximum and minimum temperature, but a negative correlation was found between mean monthly values of humidity grade and indicators of rainfall. Souêtre et al. (1987;1990)'s studies on the relationship between suicide and meteorological and geophysical variables revealed that the critical environmental factors affecting the annual suicide rhythm and regional distribution of suicides seemed to be sunlight duration and ambient temperature (as the monthly mean temperature). The present study supports these findings to some extent. The Danish suicide rate generally shows a positive correlation with exposure to sun and (max) temperature. We found that high maximum temperature and dry air are significantly associated with an increase in the incidence of suicides, whereas snow-covering and low minimum temperature are associated with fewer suicides. Similar results were reported by Odewald (1931), who ascribed higher incidence of suicide to very dry, hot weather, e.g. fohn winds in Germany and Switzerland, and Schramm (1968), who observed an increase in suicide rate on warm days and fewer suicides than expected on cooler days.

Particularly sunlight (luminance) seems to be correlated with the spring peak in suicide incidence. The spring peak in suicide incidences is immediately after the vernal equinox (21st of March), the approximate starting point of the photoperiodicity (long vs. short days) followed by increasing light and temperature amounts. Several scholars have observed a significant association between suicide and increased hours of sunshine and lower levels of relative humidity (Salib, 1997; Salib & Gray, 1997). Also Aschoff (1981), Maes et al. (1994) and Linkowsky et al. (1992) have shown a significant relationship between length of day (sunlight duration) and suicide rate, and between hours of sunshine and suicide rate. It has been speculated that sunshine exposure might in fact have a triggering effect on suicidal behaviour through regulation of seretonin or melatonin levels (Petridou et al., 2002), or that seasonal fluctuations may be related to the effect of light on the pineal gland (Parker & Walter, 1982). Based on our findings, we cannot confirm nor reject these hypotheses.

In a Danish study, Dam et al. (1998) found that weather conditions clearly influenced depressed individuals, in that short cloudy or foggy days as well as rain and cold weather having a negative influence and long warm sunny and dry days have a positive influence on depression. Apparently, biological theories are insufficient to explain an increase in the suicide incidence on bright days, which the present study suggests. Based on this, we find it appropriate to apply a combination of the socio-demographic and the psychosocial theories, presented in the introduction. In contrast to the social hibernation in winter, the intensity of social activity increases drastically during the brighter days in springtime, leaving suicidal persons in a position to compare themselves to others. In doing this, they might experience their life as being more unfulfilling or unbearable than before. During winter, suicidal persons might externalize inner misery to the weather, but as spring arrives it becomes far more likely for them to internalize their emotional distress. Combined with the possibility of severely

depressed, suicidal persons being negatively affected by disappointments of unmet expectations in spring, as Gabennesch (1988) has speculated, it may have a triggering effect on suicidal behaviour. Gabennesch's theory can thus be used to explain seasonal fluctuations in depression levels. Dysphoric moods seem to be especially prevalent in winter, but depressed individuals nevertheless hope for a relief from their distress in the springtime. Some people fail to find relief, and precisely these people face the risk of ending up as suicides in late spring or early summer.

It is possible to support the theory of broken-promises by cognitive research on suicidal persons. Cognitive distortions, such as dichotomous thinking and overgeneralization, likely associated with increased vulnerability to the "broken-promise-effect", have been associated with suicidal ideation. Dichotomization might exaggerate the possibility of relief to be brought by the arrival of spring and consequently enhance the feeling of despair when expectations remain unfulfilled. Overgeneralization, on the other hand, may lead the despondent individual to the conclusion that relief from depression will never occur (Noble, 1996). Especially vulnerable individuals thus tend to build up utopian, grandiose and unrealistic expectations which cannot be fulfilled, resulting in frustration, disappointment and ultimately hopelessness, which has been repeatedly shown to be strongly correlated with suicidal behaviour (Lester, 1992).

Weather changes

Some researchers have speculated that weather changes may have an impact on suicidal behaviour (Jessen et al., 1998). Bouma & Tromp (1972) reported an apparent psychological and physiological effect of weather on persons predisposed to commit suicide. Especially frontal passages, with rapid and drastic temperature changes, strong winds and heavy

precipitation seemed to be influential. In Denmark, Waehrens (1981) found a significant increase in the incidence of suicide in periods of dropping air pressure and, conversely, a decrease in the suicide rate in periods of rising air pressure. In the present study we found that several meteorological factors in autumn are positively associated with increased suicide risk, e.g. fog. This is supported by Heigel (1974), who observed an increase in suicides taken place during foggy weather or during sudden weather changes. We also found that sudden changes in weather can postpone or shield against suicidal behaviour, unless it is a change to cold weather or from very hot or dry weather (table 3). These findings are somewhat inconsistent with most of the previous studies. Recent studies indicate that sudden changes in weather, particularly in environmental temperature and humidity degree, appear to be associated with an increase in the number of suicide (Maes et al., 1994; Wang et al., 1997). Various other authors have observed a link between warm days or a passage of warm fronts followed by large temperature differences and increased suicide rate. Dixon & Shulman (1983) noted that rapidly increasing temperatures and the building up of warm fronts are possibly correlated with an increase in the incidence of suicide.

Limitations of the study

The most salient methodological problems in studies of suicide seasonality are probably an inadequate number of events, short time series, poor statistical techniques, and a lack of control for extraneous factors influencing suicide rates (Kevan, 1980; Souêtre et al., 1987). Small sample size may likely lead to lack of power in statistical significance tests or to a Type II error, i.e. the 'no association' finding between suicide and weather parameters (Salib & Gray, 1997). Furthermore, in statistical series against time, it is preferable to have a long time series in order to distinguish random fluctuations from systematic ones. The results in the

present study, however, are quite statistically powerful because of the long series of data available, and, as far as suicides are concerned, the large sample size makes it easier to ascertain stable and reliable trends. In the present study, the data of attempted suicides were available only from the period of 1989-2000 and only for the County of Funen. This is likely the reason why the results are inconclusive. Little attention has been paid to seasonal influences on attempted suicides, and because of the insufficient data concerning this area of research it is still somewhat uncertain whether attempted suicides also have a clear asymmetry linked to seasonal change and concomitant climate variance.

Seasonal changes in the environment possibly underlie and influence biological processes, not to mention psychosocial factors and socio-cultural habits, which contribute to suicidal behaviour (Hakko, 2000; Chew & McCleary, 1995). But as Preti & Miotto (1998) have noticed, it is rather difficult to isolate the specific influence of a single meteorological variable on suicidal behaviour. Likewise it is difficult to separate climatic influence from social factors. The vast majority of studies of weather and suicide have failed to make a distinction between the primary influence of meteorological variables and an occasional link (Preti, 1998), due to their mere recurrence in line with the seasons. It is thus difficult to distinguish the bio-meteorological effects from the indirect effect of social and cultural habits or demographic composition. This poses a serious limitation on the study of meteorological effects on human behaviour.

Since this study is dependent on the possibility of obtaining accurate information on the time-of-death for all suicides, it may be a problem that some people are found several days after the suicide, thus causing problems in determining the exact weather condition on the time-of-death. The obvious difficulty in determining the exact time-of-death is an obstacle in all studies on the influence of daily weather factors on suicide.

Furthermore, the use of static weather codes and the distant location of the meteorological office from the main part of the study population may influence the study findings negatively (Salib & Gray, 1997). A possible discrepancy in weather conditions among different areas in the country thus needs to be taken into account. There may be geographical variation in weather, particularly in regard to specific weather phenomena, such as fog or precipitation.

It is somewhat unclear whether meteorological influences on suicidal behaviour are instantaneous or delayed. If the latter is the case, the spring peak in completed and attempted suicides could partially be attributed to a slow maturation of suicidal intentions beginning in winter. Paradoxically spring may actually provide the energy to act on the intentions. It is commonly known that the time of greatest risk for completed suicide is when people are improving, possibly because that is when they have the energy to act out a dormant suicide plan.

In addition to this, we did not differentiate between violent and non-violent suicides. Method of suicide appears to be associated with seasonal variations in weather conditions. Maes et al. (1993*a*) have shown that suicides by violent methods in Belgium have a clear seasonal variation and that suicides by non-violent methods display no such seasonality. This testifies to the role of impulsive behaviour in suicides and suicide attempts. The aim of this study, however, is not to investigate the method specific seasonal distribution of mortality from suicide. Since we did not differentiate between various methods of suicide in this study, our findings could be distorted by the fact that whereas violent suicides seem to be associated with temperature and sunlight duration, non-violent suicides may not be (Linkowski et al., 1992; Maes et al., 1993*a*). Additional research is required to elucidate these possibilities.

Finally, as to the "theory of broken promises" (Gabennesch, 1988), questioning serious suicide attempters to explore whether or not the season has any effect on their conscious motives, would be a possible method in future research (Lester & Frank, 1988).

5. Conclusion

Suicide seasonality seems to be a ubiquitous and insufficiently understood phenomenon. We believe that identification and explanation of the dominant seasonal patterns in completed and attempted suicides are important in the understanding of the possible sociological, psychological and biological factors, which may influence suicidal and pre-suicidal behaviour. The present study provides some evidence to support the socio-demographic, as well as the psychosocial and the bio-meteorological hypotheses. The results in this study suggest an association between seasonal change, probably interacting with biological and social variables, and suicidal risk. We are not making any suggestions about weather conditions and the *causation* of suicidal behaviour, but merely pointing at the possibility of weather conditions being associated with the suicidal behaviour of some people. The observed seasonal variation in suicides in Denmark seems to be – at least in part – associated with the seasonal rhythms of environmental factors, such as duration of sunlight, temperature, atmospheric pressure and humidity grade. It is worth noticing, however, that even if meteorological factors are related to suicide risk, whatever large or small the influence may be, they represent but a few of the multiple factors involved in the heterogeneous aetiology of suicide. Several authors have attributed this relationship to biological influence. This study, however, does not intend to examine neurochemistry or psychobiology. As Chew & McCleary (1995) have noted, the bio-meteorological factors seem to have some effect on the seasonality of suicides, but this effect is conditional on e.g. socio-demographic factors, such

as unemployment rate, or monthly birth rates. It is possible to consider weather to be an intermediate variable (Kevan, 1980).

Knowledge of temporal fluctuations in suicidal behaviour may prove to be relevant and useful in regard to suicide prevention measures, especially for staffing and securing accessibility to prevention and intervention services (e.g. crisis hotlines and hospitals) in high risk times - as well as timing training for new volunteers (Noble, 1996).

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Statistical appendix.

We assume that a stochastic variable X (the daily number of suicides/attempted suicides) follows a Poisson distribution. The probability of x suicides on a specific day is:

$P(X = x) = \lambda^x \cdot e^{-\lambda}/x!$, x = 0, 1, 2 ……. and $\lambda = \lambda i$ (i = number of the day)

λ is the expected, but unknown, number of suicides and may be estimated

Within the same year, month, and day of the week (4 or 5 days) we assume that the number of suicides is only differentiated with respect to a binary meteorological factor under investigation. And X_1 the number of suicides on days with the investigated weather factor present and X_0 the number of suicides on days without weather factor the conditional test of:

$P(X_1 = x_1 \mid X_1+X_0 = x_1 + x_0) \sim bi\ (n, p)$, $n = x_0+x_1$ and $p = \lambda_1/(\lambda_1+\lambda_0)$

The addition theorem of binomial distributions allow summation of independent binomial stochastic variables with the same parameter p. ($X_1 = \sum X_{1i}$ and $n = \sum n_i$).

If n and p are large ($n \times p \times (1-p) > 9$) X_1 follows a normal distribution (where $\mu = n \times p$ and $\sigma^2 = n \times p \times (1-p)$).

The addition theorem for normal distributions imply that summation of a number of stochastic variables X_i where $X = \sum X_i$ follows a normal distribution with $\mu = \Sigma \mu_i$, and $\sigma^2 = \sum \sigma_i^2$.

The approximations reduce a number of tests into one test for each meteorological factor. Two-tailed probabilities of significance are used. A significance level of 0.01 (0.001 for monthly weather factors) is chosen, since the great number of calculated factors increases the risk of type II errors.

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Table 2. Suicide and weather factors by month. percentage deviation from expected and significance (Bold: significance < 0.001)

	Fewer Suicides			**More suicides**		
	Weather factor	Pct. dev.	significance	Weather factor	Pct. dev.	significance
Jan.				Fog part of the day	7.6	0.0064
Feb.	**Low (min. temperature)**	**-18.4**	**0.0000**	1-5 mm rainfall	8.4	0.0010
	Very low min.temperature	**-18.0**	**0.0001**	Rainfall	6.5	0.0079
	Very low (mean temperature)	**-15.5**	**0.0002**	Large change of humidity	5.6	0.0063
	Very low (temperature)	**-15.1**	**0.0001**			
	Very low (max. temperature)	-12.8	0.0031			
	Dry weather	-5.6	0.0071			
March	Snow-cover	-12.3	0.0032	No snow-cover	6.1	0.0015
	Mean sunshine	-5.1	0.0057			
May	Abs. humidity normal	-5.4	0.0011	Low min. humidity	6.7	0.0059
				Low abs. mean humidity	**6.3**	**0.0009**
June				Very high (temperature)	11.5	0.0071
Aug.	Abs. humidity normal	-4.2	0.0071	**Very high (max. temperature)**	**14.4**	**0.0005**
				Very high (mean temperature)	11.1	0.0075
				Light day	**9.0**	**0.0009**
				Low min. humidity	6.8	0.0079
				Low abs. mean humidity	6.7	0.0021
Sept.	Large change of humidity	-5.3	0.0049			
Oct.	Very low (temperature)	-11.9	0.0071	Fog part of the day	7.9	0.0036
	Large change of humidity	-4.7	0.0099			
Nov.	Normal max. wind force	-5.9	0.0022	Fog (mean visibility)	35.0	0.0025
				High min. humidity	9.2	0.0013
				High mean humidity	8.2	0.0021
				calm (max.wind force)	7.8	0.0063
Dec.	Day-frost	-12.8	0.0077			

Table 3. Suicide and weather changes. percentage deviation from expected and significance (Bold: significance < 0.01)

Fewer Suicides			**More suicides**		
Weather change	Pct. dev.	significance	Weather change	Pct. dev.	significance
To very high (max. temperature)	**-9.5**	**0.0063**	To low (temperature)	4.7	0.0395
To nordic summer day	**-8.5**	**0.0003**	From very high (min. temperature)	4.0	0.0317
To no snow-cover	-8.1	0.0366	From dry weather (amount of precipitation)	2.3	0.0335
To low air pressure (abs. mean air pressure)	**-7.4**	**0.0093**			
From snowfall	**-6.7**	**0.0035**			
From very low (max. temperature)	**-6.1**	**0.0012**			
From snowfall (1-5 mm water eqv..)	**-6.1**	**0.0096**			
From (very) low (mean temperature.)	**-5.1**	**0.0006**			
To (very) high (temperature)	-4.4	0.0127			
From low (mean temperature)	-4.4	0.0102			
To dry air (min. humidity)	**-4.3**	**0.0075**			
From low (mean temperature)	**-4.1**	**0.0034**			
To dry air (mean humidity)	-3.9	0.0218			
From (very) low (max. temperature)	**-3.8**	**0.0069**			
From fairly low (max. temperature)	**-3.6**	**0.0058**			
From windy (max. wind force)	**-3.6**	**0.0028**			
From large change in visibility	**-3.2**	**0.0023**			
From (very) low (temperature)	-3.1	0.0269			
To light cloudy and no clouds	-3.1	0.0322			
From normal max. humidity	-3.0	0.0131			
To large change of humidity	**-2.8**	**0.0088**			
From 1-5 mm precipitation	-2.5	0.0104			
From max. wind force > 8 m/sek	-2.5	0.0242			
To dry weather	-2.5	0.0312			
From large change in mean wind force	-2.4	0.0167			
From normal mean humidity	-2.2	0.0300			
From half cloudy	-2.1	0.0309			