Unusual association of diseases/symptoms

Wind direction and mental health: a time-series analysis of weather influences in a patient with anxiety disorder

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Summary

Time-series analysis was used to study the associations between daily weather variables and symptomatology in a man suffering from recurrent anxiety. Outcome measures were the patient's main symptoms: anxiety and energy. Wind direction appeared to be related to the patient's energy levels; these were significantly lower when the wind blew from the southeast. This effect could not be explained by other weather parameters. Decreases in energy in turn predicted increases in anxiety. The reverse effect was observed as well, with increases in anxiety predicting decreases in energy, indicating a positive feedback loop.

BACKGROUND

Systematic research on the effects of wind direction on mental health is scarce.¹ This is remarkable, as there are many local reports of notorious winds coming from a particular direction and referred to as 'ill winds' or 'winds of depression'. For example, central European countries have *Foehns*, dry southerly winds blowing over the Alps and associated with 'Föhnkrankheit' and increased suicide. Similarly, psychological distress has been reported to be related to winds like *Santa Ana* (California), *Hamsin* (Middle East), *Mistral* (southern France) and *Sirocco* (Italy). Another hiatus of research on weather influences on mental health is that most studies have been done in the context of seasonal affective disorder,^{2–3} focusing on depression and leaving other mood states, such as anxiety, unaddressed. Moreover, this research has mainly centred on seasonal weather influences (eg, seasonal differences in sunlight and temperature). Seasonal weather influences, however, are not the same as day-to-day influences.^{4–5}

We evaluated the effects of daily weather parameters on mental health in a patient suffering from anxiety, using an intensive time-series design.⁶ Our main focus was on the wind direction, but we studied other weather parameters as well, since effects of wind direction may be confounded or cancelled out by other weather parameters.

CASE PRESENTATION

The patient was a middle-aged man with a 25-year history of recurrent episodes of anxiety. In the fall of 2008, he was readmitted as an outpatient to the Center for Integrative Psychiatry (Groningen, the Netherlands), because of a relapse of anxiety after accepting a job for the first time in many years. He had been unemployed for 2 years because of his symptoms and because his wife had died of breast cancer, after which he had to take full parental responsibility for his four daughters aged 10 to 18. Just before his readmission he was told that his oldest daughter carries the same breast cancer gene as his wife. He experienced a general feeling of anxiety and fear, and

mild depressive symptoms but no specific phobias or panic attacks. He also had many physical symptoms like fatigue, low energy and nausea. The patient did not meet the criteria for any specific anxiety disorder. The clinical diagnosis made by the therapist was anxiety disorder NOS and cluster C personality traits.⁷

INVESTIGATIONS

The patient recorded his main symptom scores on a daily basis by means of a diary. These recordings were part of the treatment. The patient's two main symptoms were identified during the intake interview and were (low) energy and anxiety. The patient was instructed to score the intensity of these symptoms in two columns of the diary, on a scale from 0 to 10. Higher scores denote more energy and more anxiety. The validity and reliability of single self-report diary items for the assessment of anxiety and lack of energy has been shown in a number of studies.^{8–10} The diary also included a column in which the patient could register special events and changes in medication. Daily completion of the diary started as soon as the treatment started, on 23 October 2008, after the intake interview. The patient continued his recordings until 15 June 2009, resulting in a series of 236 assessment points with no missing values.

Weather data were obtained from the Royal Netherlands Meteorological Institute (<http://www.knmi.nl/klimatologie/daggegevens/selectie.cgi>), selecting the weather station near the patient's home. The following daily weather variables were retrieved: vector-average wind direction (360° = north, 90° = east, 180° = south, 270° = west), vector-average wind velocity (m/s), mean temperature (°C), hours of sunlight, hours of precipitation, mean air pressure (hPa), mean relative humidity (%) and mean cloud cover (eight categories). The wind direction describes the predominant direction from which the wind is blowing that day. We recoded the wind direction into four categories: northeast, 0°–90°; southeast, 90°–180°; southwest, 180°–270°; northwest, 270°–360°, and used

three dummy variables denoting these categories in the analyses (southeast = reference category).

The time series of the patient were investigated using a technique for the analysis of multiple time series called vector auto regressive (VAR) modelling.^{11 12} A VAR model is a multivariate autoregressive model that consists of a set of regression equations for a system of two or more variables.¹² In the present study, a two-variable VAR was used, with equations for Anxiety and Energy. These variables were treated as endogenous, which means that they can be both determinant *and* outcome, allowing for bidirectional influences between these symptoms. The weather variables were treated as exogenous to the system, which means that they may influence the system but cannot themselves be influenced by the system. In VAR, each of the endogenous variables is regressed on its own lagged values and the lagged values of the other variables. The error terms should be serially uncorrelated but can be contemporaneously correlated. The number of lags that is needed in the model can be determined using lag-length selection criteria such as the Likelihood Ratio Test, Final Prediction Error, Akaike Information Criterion, Hannan-Quinn Information Criterion and Bayesian Information Criterion. The optimum lag length is the one that minimises goodness-of-fit statistics.¹¹

To account for the potential effects of medication (inositol, paroxetine and alprazolam), we added control variables denoting the dosages of these drugs to the model. We controlled for the occurrence of treatment contacts (0/1) as well. As alprazolam and treatment contact did not contribute significantly to the model, these parameters were removed from the final model. After estimation of the VAR, we examined whether the coefficients of parameters not contributing to the model could be constrained (set to 0).¹¹ The VAR was re-estimated after placing each constraint. The Bayesian Information Criterion was used to compare the fit of successive models. If this criterion did not indicate a worsening of model fit, the constraint was retained. Parameters with the highest p-values were constrained first (until $p = 0.100$). We checked whether the final VAR model was correctly specified using diagnostic tests on stability and residual autocorrelation.¹¹ As the Energy and Anxiety series showed heteroskedasticity (non-stationary variances), we used the natural logs of these variables to stabilise the variances.¹² This implies that the regression coefficients can be interpreted in terms of percentages. A two-tailed α level of 0.05 was used to determine statistical significance. Analyses were performed in STATA 11.

TREATMENT

The regular course of treatment given at our centre was followed, which consisted of psychiatric counselling and lifestyle training combined with psychotropic medication or nutritional supplements. During the study period, the patient had regular therapy contacts with his psychiatrist, 17 contacts in total (mean duration = 33 min, range 5–55 min). During these contacts, the therapist discussed the patient's symptom course and reinforced healthy lifestyle changes. He further used an eclectic supportive psychotherapeutic approach, focusing on unconditional positive regard, adjusting to the patient's needs and preferences and helping him regain a sense of control. During

the first half of the study, the patient used 2–4 g inositol, a naturally occurring compound that is a member of the B-vitamin family. The patient did not come near the supposed efficacy threshold for inositol at any moment during the study period (the effective dosage is 12–18 g). In the second half of the study period (day 123), he switched to paroxetine because he regarded the inositol effect, though present, as too slow and too weak. The patient gradually increased the dosage paroxetine to 40 mg in 4.5 weeks and continued to take this dosage until the end of the study period. On Christmas day, he started to add alprazolam to his medication, at his own initiative. Alprazolam is a benzodiazepine that is used as an anxiolytic. During the following 3 months, the patient took one to three tablets of 0.25 mg alprazolam on the days he felt the need to do so (38 days in total). He recorded his use of benzodiazepine in the diary.

OUTCOME AND FOLLOW-UP

Daily symptom pattern

Figure 1 shows the time series of the patient's daily Anxiety and Energy levels, as well as the average wind direction for each day of the study period. During the study period, the wind blew most often from the southwest (44% of the days). The other wind directions were far less frequent: northeast, 23%; northwest, 18%; southeast, 15%. Anxiety and Energy scores of the patient showed a fluctuating pattern from day to day. Over the longer term, Energy scores gradually increased, whereas Anxiety scores gradually decreased. The Christmas period was a major exception, when Anxiety scores showed a marked increase. According to the patient's diary notes and his account during the therapy contacts, the days around Christmas had been very burdening for him. He experienced a major crisis as a result of a coincidence of stressful events: getting back to work for the first time since long, worries concerning his daughters, and the many social events surrounding Christmas bringing back memories of his deceased wife. To control for possible confounding effects due to this unusual time of the year, we included a dummy variable denoting the Christmas period (coded '1' for the 10 days around Christmas and '0' otherwise) as a control variable in the VAR model.

Estimation of the VAR model

First, we determined how many time lags were needed in the VAR model. Most lag-length selection criteria suggested an optimal lag length of 2, some suggested including 1 lag. We tested both a 1-lag and a 2-lag VAR, but as the former showed considerable residual autocorrelation, we proceeded with the 2-lag model. Next, the VAR with 2 lags was estimated. Table 1 presents the final VAR model in which the two endogenous variables (Energy and Anxiety) were modelled as a function of their own previous values (lags 1 and 2), the previous values of the other endogenous variables, and the exogenous variables (wind direction and control variables). With regard to the control variables, inositol and paroxetine were significantly related to Energy and Anxiety, with higher dosages of inositol and paroxetine going together with more Energy and less Anxiety. Further, a strong relationship was found between the Christmas period and Anxiety (0.321, 95% CI = 0.173 to 0.469, $p < 0.001$). A substantial

Figure 1 Time series of Energy and Anxiety (range 0–10) from 23 October 2008 until 15 June 2009 (236 days). The bottom graph shows the predominant wind direction for each of these days.

increase in Anxiety was noted in the days around Christmas. This Christmas effect was highly significant.

Wind direction

The effect of wind direction was modelled with three dummy variables. We performed a joint hypothesis test (Wald test) on the estimates of these parameters, to test the null hypothesis that wind direction made no difference to Energy or Anxiety. The joint hypothesis test for the effect of wind direction on Anxiety was not significant ($\chi^2(3) = 3.29$, $p = 0.349$). Therefore, the coefficients for the wind direction parameters in the Anxiety equation were

constrained. The joint hypothesis test for the effect of the wind direction on Energy was significant ($\chi^2(3) = 8.09$, $p = 0.044$). So, the wind direction did make a difference to the Energy scores of the patient. As can be seen in table 1, Energy scores were significantly lower when the wind blew from the southeast (the reference category) as compared to the other wind directions (southwest vs southeast: $B = 0.045$, 95% CI = 0.005 to 0.085, $p = 0.029$; northwest vs southeast: $B = 0.058$, 95% CI = 0.011 to 0.105, $p = 0.016$; northeast vs southeast: $B = 0.060$, 95% CI = 0.015 to 0.105, $p = 0.009$) (see also figure 2). The differences among the three other wind directions were not significant

Table 1 Estimates from the vector autoregressive model

Parameter	Dependent variables	
	Energy _t	Anxiety _t
Energy _{t-1}	0.426***	—
Energy _{t-2}	0.219***	−0.259*
Anxiety _{t-1}	−0.072**	0.474***
Anxiety _{t-2}	—	0.231***
Exogenous variables		
Inositol	0.019*	−0.046**
Paroxetine	0.002*	−0.008***
Christmas	—	0.321***
Wind direction		
Southeast	Ref	Ref
Southwest	0.045*	—
Northwest	0.058*	—
Northeast	0.060**	—
R ²	0.84	0.71

Note: Energy and Anxiety are natural log-transformed variables. Coefficients denoted with '—' are constrained (set to 0). Ref = Reference category. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure 2 Raw Energy scores (range 0–10) by wind direction. *Estimated mean differences between the southeast category and each of the other wind directions are significant (see table 1).

(southwest vs northwest: $B = -0.013$, 95% CI = -0.050 to 0.024 , $p = 0.487$; northwest vs northeast: $B = -0.002$, -0.039 to 0.044 , $p = 0.922$; northeast vs southwest: $B = 0.015$, -0.019 to 0.050 , $p = 0.386$). Together, the parameters in the model explained 84% of the variance in the Energy series and 71% of the variance in the Anxiety series.

Dynamic relationships between Energy and Anxiety

Both the Energy and Anxiety series showed important positive autocorrelation; current values of these variables were related to values of the two previous days. Besides these autoregressive effects, the variables showed some lagged correlations with each other. Energy scores at $t-1$ were related to current Anxiety scores: higher levels of Energy were followed by lower levels of Anxiety 2 days later. The reverse effect was also present, with increases in Anxiety being related to decreases in Energy the following day. The contemporaneous correlation between Energy and Anxiety, which is not shown in table 1 but was retrieved from the regression residuals,¹¹ was -0.382 . So, there was both an instantaneous and a lagged association between Energy and Anxiety. The two symptoms mutually influenced each other, showing a positive feedback loop.

Model adjusted for other weather parameters

As it can be expected that differences in wind direction go together with differences in other weather parameters, we investigated whether the effects of wind direction on the Energy scores could be explained by wind velocity, temperature, sun hours, precipitation hours, air pressure, humidity or cloud cover. To this end, we added these parameters to the model of table 1. The results remained essentially the same. None of the extra weather parameters contributed significantly to the model. The effects of the dummy variables for wind direction on Energy remained significant, and also the size of the estimates remained about the same. All other effects remained significant as well, except the paroxetine effect in the Energy equation, which was reduced to 0.001 ($p = 0.176$). We concluded that the effect of wind direction on Energy could not be explained by other aspects of the weather.

DISCUSSION

We studied daily symptom fluctuations in a patient suffering from recurrent anxiety disorder, and found that energy levels were lowered by wind from the southeast. Further, we found a positive feedback loop between energy and anxiety. While in Western culture the idea that wind might influence mental health may strike some as odd, this idea is not as strange as it may sound. In the East, this concept is a basic premise in Ayurveda (traditional medicine in India), and also in traditional Chinese and Tibetan medicine.^{13 14} In Ayurveda, one of the principal terms for madness is 'vatula', literally meaning 'inflated with wind'. In traditional Chinese medicine, wind is one of the six 'pernicious influences' and is considered to be a major cause of illness.

Empirical research on the relationship between wind direction and mental health is scarce. Bulbena *et al*¹ studied wind direction in relation to psychiatric emergencies in a hospital in Barcelona. Interestingly, they found that panic attacks were more common on days with *poniente* wind. This is a warm inland wind coming from the west of

Barcelona. Warm and dry winds are known to increase the atmospheric concentration of positive ions.¹⁵ Further, there is some literature describing the 'exhaustion syndrome'.¹⁶ This syndrome is associated with warm winds and includes symptoms such as hypotension, fatigue, apathy, lack of concentration and hypoglycaemia, and is thought to be related to electric charges of the air.¹⁶ The relevant evidence, however, is mainly based on animal research.

The fact that we were able to measure an effect of wind direction on energy may have been because of the power of our intensive single-subject time-series design. Certain weather influences may go unnoticed in conventional group studies, because these studies are based on *inter*-individual variation at a single point in time instead of *intra*-individual variation over time. The implicit assumption in such studies is that correlations derived at the group level can be generalised to the individual level, which is not necessarily true.^{17 18} Moreover, group studies may obscure individual differences in meteorological sensitivity and subtle weather effects on symptom dynamics. Also subtle effects, however, can be important, as their accumulated effects may be substantial, especially if they are enhanced by other effects. For example, an increase in energy upon northeastern wind may lead to a decrease in anxiety, which in turn may lead to a further increase in energy, and so on. In this way, a favourable wind direction may induce a positive spiral, especially if this wind holds on for a longer period of time. The same feedback loop may also keep someone caught in a vicious cycle, if he lives in a country where the prevailing wind is from the wrong direction.

This study represented naturalistic data from a patient treated at our centre and willing to conscientiously report his complaints over a long period of time. These data, coupled with freely accessible meteorological parameters enabled us to explore the effects of wind and Christmas on affect in a very detailed, microscopic way. An important strength of this study was that the patient was not aware of the possibility that we would link his data to meteorological parameters at the time of the recording. This prevented reporting bias due to implicit common sense theories about mood-weather relationships. Time-series analysis helped us to 'know which way the wind blows' for this individual. An important limitation is that we do not know whether these findings generalise to other persons, in other words that our findings may represent 'a tempest in a teapot'.

Learning points

- ▶ Warm, inland wind can lower energy levels.
- ▶ Low energy levels and anxiety symptoms can mutually reinforce each other.
- ▶ Time-series analysis can give a detailed and patient-specific account of symptom dynamics and can reveal subtle environmental influences on psychopathology.

Competing interests None.

Patient consent Obtained.

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Bos EH, Hoenders R, de Jonge P. Wind direction and mental health: a time-series analysis of weather influences in a patient with anxiety disorder. *BMJ Case Reports* 2012;10.1136/bcr-2012-006300, Published XXX

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