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Can Expectations Produce Symptoms From Infrasound Associated With Wind Turbines?

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Objective: The development of new wind farms in many parts of the world has been thwarted by public concern that subaudible sound (infrasound) generated by wind turbines causes adverse health effects. Although the scientific evidence does not support a direct pathophysiological link between infrasound and health complaints, there is a body of lay information suggesting a link between infrasound exposure and health effects. This study tested the potential for such information to create symptom expectations, thereby providing a possible pathway for symptom reporting. ***Method:*** A sham-controlled double-blind provocation study, in which participants were exposed to 10 min of infrasound and 10 min of sham infrasound, was conducted. Fifty-four participants were randomized to high- or low-expectancy groups and presented audiovisual information, integrating material from the Internet, designed to invoke either high or low expectations that exposure to infrasound causes specified symptoms. ***Results:*** High-expectancy participants reported significant increases, from preexposure assessment, in the number and intensity of symptoms experienced during exposure to both infrasound and sham infrasound. There were no symptomatic changes in the low-expectancy group. ***Conclusions:*** Healthy volunteers, when given information about the expected physiological effect of infrasound, reported symptoms that aligned with that information, during exposure to both infrasound and sham infrasound. Symptom expectations were created by viewing information readily available on the Internet, indicating the potential for symptom expectations to be created outside of the laboratory, in real world settings. Results suggest psychological expectations could explain the link between wind turbine exposure and health complaints.

Keywords: psychological expectations, symptom reporting, environmental risks, wind energy, infrasound

Harnessing wind energy is a critical component of long-term strategies for securing sustainable power supply in countries throughout the world, with the potential to help address global climate change (Markandya & Wilkinson, 2007). However, recent opposition to wind farms has seen a substantial increase in rejection rates for new wind farm developments (e.g., Smith & Prosser, 2011), which threatens the achievement of renewable energy targets. Much of the opposition to wind farms stems from the belief that the infrasound produced by wind turbines causes health complaints in nearby residents. Although there is no empirical support for claims that infrasound generated by wind turbines could trigger adverse health effects (Bolin, Bluhm, Eriksson, & Nilsson, 2011), there has been a lack of other plausible mechanisms that could explain the experience of nonspecific symptoms reported by some people living in the vicinity of wind turbines. In this study we investigate whether exposure to information that creates negative expectations about symptoms from infrasound could be a possible explanation for this relationship.

Exposure to infrasound, which occurs when the frequency of a sound wave is below the low frequency limit of audible sound (approximately 16 Hz), is a ubiquitous human experience. Infrasound is consistently present in the environment caused variously by air turbulence, ocean waves, traffic, and other machinery and is also produced in the body by processes such as respiration and heartbeat (Bedard & Georges, 2000; Leventhall, 2007). Although infrasound may be audible at sufficiently high pressure levels (decibels), infrasound produced by wind turbines is subaudible (Leventhall, 2006; O'Neal, Hellwig, & Lampeter, 2011), and health effects of infrasound below the threshold of human perception have not been found (Health Protection Agency, 2010).

Although the scientific evidence does not support a direct pathophysiological link between the generation of infrasound by wind turbines and health complaints, there is a body of lay information on the Internet and from other sources suggesting a link between infrasound exposure and health effects (e.g., Pierpont, 2009). Furthermore, opposition to the construction of turbines is often founded on media reports that a number of people living within the vicinity of wind farms experience a range of nonspecific symptoms such as sleep disturbance, headaches, ear problems, dizziness, nausea, and heart palpitations (Simonetti & Chapman, 2012; Knopper & Ollson, 2011). Health information distributed through the media has been shown to have a powerful impact on perceptions of health and symptom reporting (Faasse, Gamble, Cundy & Petrie, 2012).

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Research indicates that the dissemination of information about potential harm from environmental factors may create health concerns that trigger symptom reporting, even in the absence of objective risk (Winters et al., 2003). This appears to occur because worry about the health impacts of exposure to a perceived environmental hazard creates symptom expectations, which has a priming effect, whereby people are more likely to notice common physiological sensations and symptoms and attribute them to an effect of such exposure (Petrie et al., 2005).

It was hypothesized that (a) during exposure to both infrasound and sham infrasound, high-expectancy participants would report significant increases in the number of symptoms and the overall intensity of symptoms experienced after exposure, and there would be no symptomatic change in the low-expectancy group; (b) high-expectancy participants would be more likely to report symptoms described as typical symptoms of infrasound exposure during exposure periods; and (c) there would be no influence of genuine infrasound exposure on symptomatic experience.

Method

A total of 54 university students (34 women, 20 men) were exposed to 10 min of infrasound and 10 min of sham infrasound (no sound). Exposure sessions, which were counterbalanced, were conducted at the Acoustic Research Centre University of Auckland, in a listening room designed for subjective listening experiments and constructed to International Electrotechnical Commission standards (IEC 268–13). Infrasound transmitted during exposure sessions (40dB at 5Hz) was created using a combination of the Adobe® Audition software package with a Presonus® Firepod audio interface, and a Mackie® HR 150 active studio woofer. Participants were told they were being exposed to infrasound during both 10-min exposure sessions and the experimenter was also unaware when exposure was to infrasound or to sham infrasound.

Following completion of baseline assessments, participants were shown the relevant expectancy video presentation, both of which were of 5 min 45 s duration. The high-expectancy presentation included TV footage, available on the Internet, containing first-person accounts of symptomatic experiences attributed to the operation of local wind farms. The low-expectancy presentation incorporated TV interviews with experts stating the scientific position that infrasound produced by wind farms would not cause symptoms.

Physical symptoms were evaluated by self-report before and during each 10-min exposure session. Participants rated their current experience of symptoms on a 7-point Likert scale ranging from 0 (*not at all*) to 6 (*extreme*). Ratings were given in relation to 12 symptoms specified to be typical symptoms of infrasound exposure (headache, ear pressure, ringing in the ears, itchy skin, sinus pressure or irritation, dizziness, pressure in the chest, vibrations within the body, racing heart, nausea, tiredness, feeling faint), and in relation to 12 symptoms identified as less typical symptoms of infrasound exposure (stomach ache, aching legs, aching arms, sore joints, stiff muscles, back pain, numbness or tingling in the body, difficulty swallowing, sore jaw, chills, hot flushes, hand tremble or shake). For each rating period, a total symptom score was calculated as the number of symptoms experienced with a rating $\geq$1. Further, for each rating period, a total symptom intensity score was calculated as the sum of the ratings given for all symptoms experienced. Reliability of the symptom self-report questionnaire was established with Cronbach's alpha ranging from .83 to .91. Participants were also asked to indicate the extent to which "I am concerned about the health effects of sound produced by wind turbines" at baseline and after screening of the video presentation. Assessment was made using a visual analogue scale, anchored by the descriptors "disagree" at 0 mm and "agree strongly" at 100 mm. Blood pressure and heart rate were monitored throughout the experiment.

To check the effectiveness of the experimental manipulation in relation to concern about the health effects of sound generated by wind farms, a one-way between-groups analysis of covariance (ANCOVA) was conducted, controlling for baseline concern scores. Mixed-model ANCOVA analysis was performed to explore within- and between-group differences in relation to change from baseline, in the number and intensity of symptoms, as well as the type of symptoms experienced during exposure periods. Stratified analysis by group was also undertaken to further explore expectancy effects on symptom reporting, heart rate, and blood pressure, using repeated-measures ANOVA.

Results

The high-expectancy group (M = 72.78, SD = 18.99) was shown to be significantly more concerned than the low-expectancy group (M = 38.00, SD = 20.01) about the health effects of sound generated by wind turbines, following the expectancy manipulation, $F(1, 51) = 48.93$, $p < .001$, $\eta_p^2 = .49$, controlling for baseline

Table 1
Mean (SD) Symptom Scores Before and During Infrasound and Sham Infrasound Exposure in the High-Expectancy (HE) and Low-Expectancy (LE) Groups

Time point	Group	Symptom score	Symptom change score	Intensity score	Intensity change score	Typical symptom score	Less typical symptom score
Infrasound							
Before	HE	6.6 (4.6)		11.2 (11.3)		4.0 (2.9)	2.63 (2.1)
During	HE	8.9 (5.2)	2.3 (4.2)	17.4 (14.8)	6.3 (11.7)	5.2 (2.9)	3.8 (2.8)
Before	LE	6.2 (3.8)		8.5 (7.0)		3.4 (2.1)	2.7 (2.2)
During	LE	5.9 (4.1)	−0.3 (3.7)	10.4 (9.5)	1.9 (6.8)	3.6 (2.5)	2.2 (2.0)
Sham							
Before	HE	6.4 (4.5)		10.0 (8.0)		3.8 (2.7)	2.6 (2.2)
During	HE	8.2 (5.6)	1.8 (2.7)	17.0 (14.8)	7.0 (10.1)	5.1 (3.2)	3.2 (2.8)
Before	LE	6.6 (4.7)		10.3 (10.4)		3.8 (2.6)	2.8 (2.6)
During	LE	6.3 (4.5)	−0.3 (3.6)	9.9 (9.6)	−0.41 (7.2)	4.1 (2.3)	2.5 (2.8)

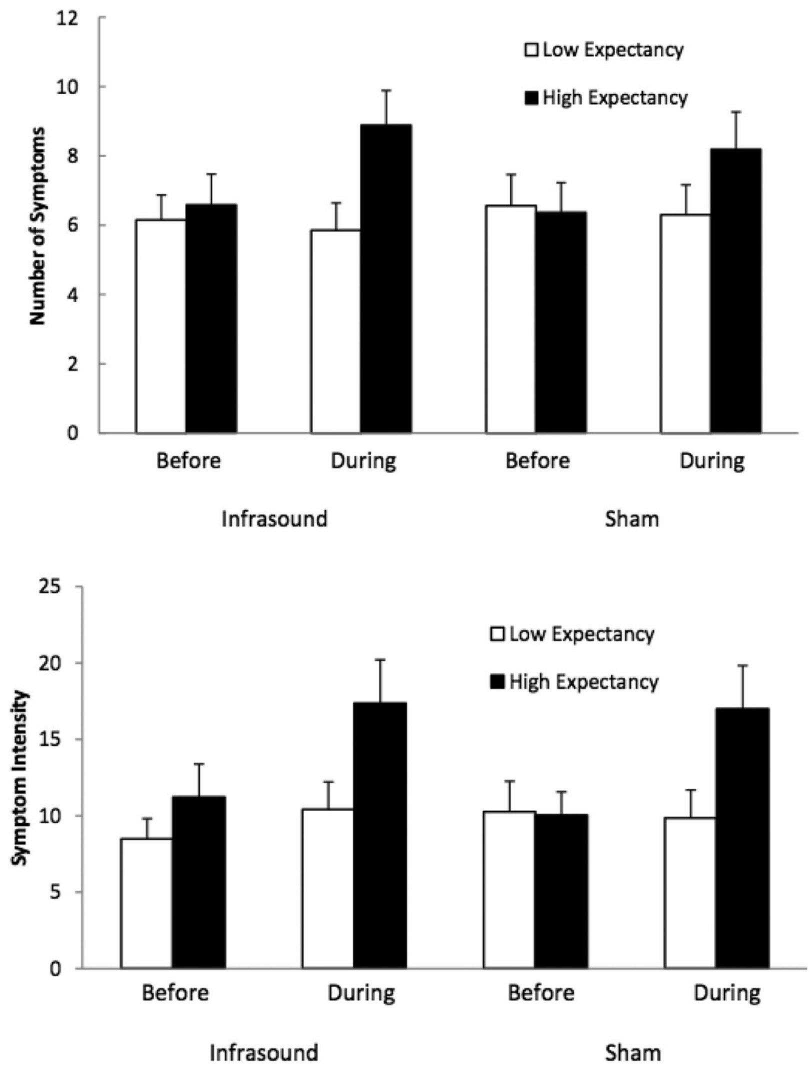

Figure 1. Total symptoms and total symptom intensity scores (means and standard error of mean) before and during infrasound exposure and before and during sham.

scores (high expectancy: $M = 44.49$, $SD = 23.78$; low expectancy: $M = 36.89$, $SD = 22.85$).

Expectancy and Symptom Reporting

Analysis using mixed-model ANCOVA conducted first in relation to symptom change scores, and second in relation to symptom intensity change scores as dependent variables, showed there were no within-group differences in relation to sham exposure symptom change scores and infrasound exposure symptom change scores, or in relation to sham exposure symptom intensity change scores and infrasound exposure symptom intensity change scores. Therefore, change from baseline in the number of symptoms reported and the intensity of the symptoms experienced was not influenced by whether exposure was to sham or to infrasound. Analysis confirmed a main effect of expectancy group on both symptom change scores, $F(1, 52) = 8.05$, $p < .01$, $r = .37$, and symptom intensity change scores, $F(1, 52) = 8.04$, $p < .01$, $r = .37$. There were no interaction effects between group and either symptom change scores or symptom intensity change scores during exposure periods. Thus the effect of expectancy group on change scores did not differ whether exposure was to sham or to infrasound (see Table 1). Therefore results indicated the number of symptoms reported and the intensity of the symptom experienced during listening sessions were not affected by exposure to infrasound but were influenced by expectancy group allocation.

Symptom Experience: Stratified Analysis by Group

As predicted, low-expectancy participants did not report any significant change from preexposure in either the number or intensity of symptoms experienced during sham or infrasound exposure. However, in the high-expectancy group, both the number of symptoms, $F(2.1,53.55) = 7.67$, $p < .001$, $\eta_p^2 = .23$, and symptom intensity score, $F(2.1,54.52) = 8.66$, $p < .001$, $\eta_p^2 = .25$, increased during exposure (see Figure 1). In accordance with

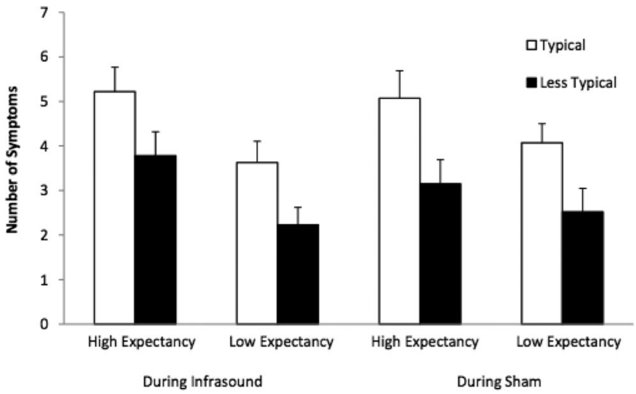

Figure 2. Number of symptoms portrayed as typical and less typical symptoms of infrasound exposure (means and standard error of mean) during infrasound and sham exposure periods.

predictions, differences were found to lie between preexposure symptom assessments and symptom reporting during exposure periods. There was a significant increase from preexposure assessment in the number of symptoms reported during exposure to infrasound, $F(1, 26) = 8.16$, $p < .01$, $r = .49$, and during exposure to sham, $F(1, 26) = 12.16$, $p < .01$, $r = .66$, as well as in symptom intensity reported during exposure to infrasound, $F(1, 26) = 7.55$, $p < .05$, $r = .47$, and during sham exposure, $F(1, 26) = 12.88$, $p < .001$, $r = .58$. Importantly, elevated symptom reporting seen in the high-expectancy group was the same during sham and infrasound exposure, confirming that infrasound exposure itself did not contribute to the symptomatic experience. No direct physiological effect of genuine infrasound exposure on heart rate or blood pressure was indicated (high-expectancy heart rate, $p = .75$; high-expectancy systolic blood pressure, $p = .26$; high-expectancy diastolic blood pressure, $p = .6$; low-expectancy heart rate, $p = .15$; low-expectancy systolic blood pressure, $p = .09$; low-expectancy diastolic blood pressure, $p = .9$).

Type of Symptoms Reported

Analysis showed a significant main effect of symptom type, $F(7, 52) = 7.21$, $p < .001$, as well as a significant symptom type by group interaction, $F(7, 52) = 2.73$, $p < .05$. Tukey-Kramer post-hoc tests revealed that, before exposure periods, participants in both groups were no more likely to be reporting typical over less typical symptoms. However, participants in the high-expectancy group reported significantly more typical symptoms than less typical symptoms during both exposure periods (see Figure 2). Further, during infrasound exposure participants in the low-expectancy group also reported significantly more typical symptoms than less typical symptoms, although the difference between the type of symptoms reported during sham exposure did not reach significance ($p = .06$).

Discussion

The study demonstrated that viewing information about infrasound integrating media reports containing accounts of the adverse health effects of living in the vicinity of wind farms, created elevated concern about the health effects of sound produced by wind turbines and increased symptom reporting during exposure sessions. These findings are consistent with environmental studies indicating that increased concern about the health risk associated with exposure to environmental hazards is associated with elevated symptom reporting, even where no objective health risk is presented (Page, Wessely, & Petrie, 2006; Schwartz, White, & Hughes, 1985). For example, following an oil tanker spill off the west coast of Wales, elevated anxiety and symptom reporting extended to people living in adjacent areas to the geographical area affected by coastal oil pollution, where there was heightened perceived risk but no exposure (Gallacher, Bronstering, Palmer, Fone, & Lyons, 2007). Degree of concern about environmental conditions in the neighborhood in which respondents are living has also been found to be associated with symptom prevalence rates in large community samples, indicating that the more concerned people are, the more likely they are to report symptoms (Lipscomb, Satin, & Neutra, 1992). This is consistent with results of this experiment which demonstrated that the higher the concern about the health effects of sound produced by wind turbines, the greater the number and intensity of symptoms participants reported during exposure periods.

Findings are also aligned with other experimental studies demonstrating that the provision of information to healthy volunteers about the potential physiological effects of exposure to an innocuous substance or sham stimulus may prompt an information congruent response during such exposure (e.g., Pennebaker & Skelton, 1981). In one such study, participants told that exposure to an electric current had the potential to cause headaches reported experiencing headaches when subjected to a sham current (Schweiger & Parducci, 1981). It is the expectation of symptoms that such information appears to impart, which is implicated in the process of triggering a symptomatic response (Rief et al., 2009). The importance of findings in this study is that symptom expectations were created by viewing TV material readily available on the Internet, indicating the potential for such expectations to be created outside of the laboratory in real-world settings.

The tendency for high-expectancy participants to report more "typical" symptoms of infrasound exposure is consistent with research indicating that the provision of information about specific symptoms associated with exposure to a perceived environmental hazard creates precise expectations that guide the types of symptoms noticed and reported during exposure to that apparent hazard (e.g., Mazzoni, Foan, Hyland, & Kirsch, 2010). Participants inhaling a benign substance, described to them as a "suspected environmental toxin," reported increases in symptoms, particularly in relation to symptoms they had been told they might expect to experience (Lorber, Mazzoni, & Kirsch, 2007). Previous research has also shown that simply learning about an illness may prime people to notice symptoms coinciding with the profile of that disease (Croyle & Sande, 1988).

It is of note that because self-report measures of symptoms are implicitly subjective, it is not possible to conclusively conclude that symptom expectations lead to an elevated symptomatic experience rather than simply leading to increased reporting of symptoms. It is also important to add that exposure to infrasound in a listening room purpose built for sound experiments may not be directly comparable to exposure to infrasound from a wind farm. This experiment only indicates the potential for symptom expectations, created by information readily available to people living within the vicinity of wind farms, to be a possible pathway for symptoms attributed to infrasound generated by wind turbines.

This study, however, provides indications that information, readily available to people living within the vicinity of wind farms, has the potential to create symptom expectations influencing reported symptomatic experiences. Given the lack of evidence for a direct pathogenic link between any aspect of the operation of wind turbines and symptom reporting, this study suggests a promising future direction for further research. Understanding the extent to which symptom expectations may be implicated in the experience of symptoms reported by people living close to wind farms is important to address symptom reporting in this group. If symptom expectations are at the heart of symptom expression, current proposals to address health concerns, such as increasing minimum set back distances for wind turbines from residences, may do little to alleviate health complaints and related opposition to wind farm development.

References

Bedard, A. J., & Georges, T. M. (2000). Atmospheric infrasound. *Physics Today, 53,* 32–37. doi:10.1063/1.883019

Bolin, K., Bluhm, G., Eriksson, G., & Nilsson, M. E. (2011). Infrasound and low frequency noise from wind turbines: Exposure and health effects. *Environmental Research Letters, 6,* 035103. doi:10.1088/1748-9326/6/3/035103

Croyle, R. T., & Sande, G. N. (1988). Denial and confirmatory search: Paradoxical consequences of medical diagnosis. *Journal of Applied Psychology, 18,* 473–490. doi:10.1111/j.1559-1816.1988.tb00030.x

Faasse, K., Gamble, G., Cundy, T., & Petrie, K. J. (2012). Impact of television converage on the number and type of symptoms reported during a health scare: A retrospective pre-post observational study. *British Medical Journal Open, 2,* e001607. doi:10.1136/bmjopen-2012-001607

Gallacher, J., Bronstering, K., Palmer, S. Fone, D., & Lyons, R. (2007). Symptomatology attributable to psychological exposure to a chemical incident: A natural experiment. *Journal of Epidemiology and Community Health, 61,* 506–512. doi:10.1136/jech.2006.046987

Health Protection Agency. (2010). Health effects of exposure to ultrasound and infrasound. Chilton, UK: Author. Retrieved from http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1265028759369

Knopper, L. D., & Ollson, C. A. (2011). Health effects and wind turbines: A review of the literature. *Environmental Health, 10,* 78. doi:10.1186/1476-069X-10-78

Leventhall, G. (2006). Infrasound from wind turbines: Fact, fiction or deception. *Canadian Acoustics, 34,* 29–36.

Leventhall, G. (2007). What is infrasound? *Progress in Biophysics and Molecular Biology, 93,* 130–137. doi:10.1016/j.pbiomolbio.2006.07.006

Lipscomb, J. A., Satin, K. P., & Neutra, R. R. (1992). Reported symptom prevalence rates from comparison populations in community-based environmental studies. *Archives of Environmental Health, 47,* 263–269. doi:10.1080/00039896.1992.9938359

Lorber, W., Mazzoni, G., & Kirsch, I. (2007). Illness by suggestion: Expectancy, modelling, and gender in the production of psychosomatic symptoms. *Annals of Behavioral Medicine, 33,* 112–116. doi:10.1207/s15324796abm3301_13

Markandya, A., & Wilkinson, P. (2007). Electricity generation and health. *Lancet, 370,* 979–990. doi:10.1016/S0140-6736(07)61253-7

Mazzoni, G., Foan, L., Kirsch, I., & Hyland, M. E. (2010). The effects of observation and gender on psychogenic symptoms. *Health Psychology, 29,* 181–185. doi:10.1037/a0017860

O'Neal, R. D., Hellwig, R. D., & Lampeter, R. M. (2011). Low frequency noise and infrasound from wind turbines. *Noise Control Engineering Journal, 59,* 135–157. doi:10.3397/1.3549200

Page, L. A., Petrie, K. J., & Wessely, S. (2006). Psychosocial responses to environmental incidents: A review and proposed typology. *Journal of Psychosomatic Research, 60,* 413–422. doi:10.1016/j.jpsychores.2005.11.008

Pennebaker, J. W., & Skelton, J. A. (1981). Selective monitoring of physical sensations. *Journal of Personality and Social Psychology, 41,* 213–223. doi:10.1037/0022-3514.41.2.213

Petrie, K. J., Broadbent, E. A., Kley, N., Moss-Morris, R., Horne, R., & Rief, W. (2005). Worries about modernity predict symptom complaints after environmental pesticide spraying. *Psychosomatic Medicine, 67,* 778–782. doi:10.1097/01.psy.0000181277.48575.a4

Pierpont, N. (2009). *Wind turbine syndrome: A report on a natural experiment*. Santa Fe, NM: K-selected Books.

Rief, W., Nestoriuc, Y., von Lilienfeld-Toal, A., Dogan, I., Schreiber, F., Hofmann, S. G., . . . Avorn, J. (2009). Differences in adverse effect reporting in placebo groups in SSRI and tricyclic antidepressant trials: A systematic review and meta-analysis. *Drug Safety, 32,* 1041–1056. doi:10.2165/11316580-000000000-00000

Schwartz, S. P., White, P. E., & Hughes, R. G. (1985). Environmental threats, communities, and hysteria. *Journal of Public Health Policy, 6,* 58–77.

Schweiger, A., & Parducci, A. (1981). Nocebo: The psychologic induction of pain. *The Pavlovian Journal of Biological Science, 16,* 140–143.

Simonetti, T., & Chapman, S. (2012). Is there anything not caused by wind farms? Retrieved from http://tobacco.health.usyd.edu.au/assets/pdfs/publications/WindfarmDiseases.docx

Smith, L., & Prosser, D. (2011, July 11). Half of planned wind farms blown away by force of local protests. *The Independent*. Retrieved from http://www.independent.co.uk/environment/green-living/half-of-planned-wind-farms-blown-away-by-force-of-local-protests-2311645.html

Winters, W., Devriese, S., van Diest, I., Nemery, B., Veulemans, H., Eelen, P., . . . Van den Bergh, O. (2003). Media warnings about environmental pollution facilitate the acquisition of symptoms in response to chemical substances. *Psychosomatic Medicine, 65,* 332–338. doi:10.1097/01.PSY.0000041468.75064.BE

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