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on

Wind Turbine Noise

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I can still hear it and it's making me ill

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Summary

A few residents near wind farms may respond negatively when the turbines are audible …… or visible. They need both inaudibility and invisibility. However, if they have developed concerns about infrasound, inaudibility is not sufficient – I can't hear it, but I know it's the infrasound which is making me ill.

There is a range of responses amongst residents, from no effect up to interference with their normal quality of life, and it is the small group at the extreme end of this range who are severely affected and who, in general, become prominent as objectors to a wind farm. They are not content with compliance of the wind farm with its criteria. They are the windfarm neighbours whom we hear about.

This paper considers why a few people react strongly to what is generally a low level of noise. To say it is because they are "noise sensitives" is merely restating their problem, without advancing understanding. The paper considers influences and factors which promote adverse responses to noise. For example, how some residents may be motivated to develop negative "mindsets", and how such mindsets may be modified.

1 Introduction

A well-designed wind farm, which meets all the required criteria, is not necessarily free from complaints. This is because the criteria for control of noise from any

source do not satisfy all those exposed to the source. Criteria are not designed to do so. Criteria, which are defined by legislators, based on information supplied by acousticians, balance competing needs and are typically set at levels for which 5%-10% of those exposed are annoyed.

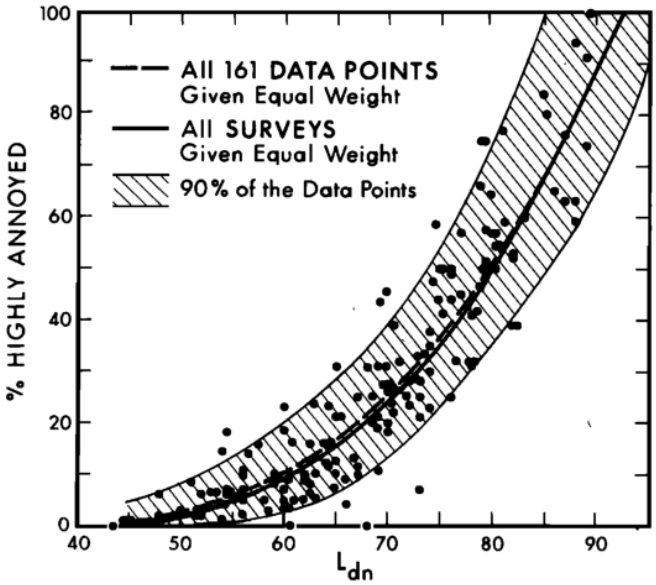

Fig 1 Shultz curve for annoyance by transportation noise

The well-known sigmoid curve, or Shultz curve , shows how annoyance varies with level, as in Fig. 1 (Schultz, 1978). This curve, which is used here for illustration, is for transportation noises, not wind turbines, but shows how there is a spread of about ±10dB of survey points around the averaged variation. There are two difficulties in use of the averaged variation.

1. If the criterion is set at, say, 10% highly annoyed, given by a sound level of about 60dB Ldn in Fig1, the spread above the average leads to the more affected people belonging to a more highly exposed average group. 2. Those who are exposed below the 10% criterion level include a small percentage of subjects who continue to be highly annoyed at very low levels and appear to be influenced by non-acoustic factors.

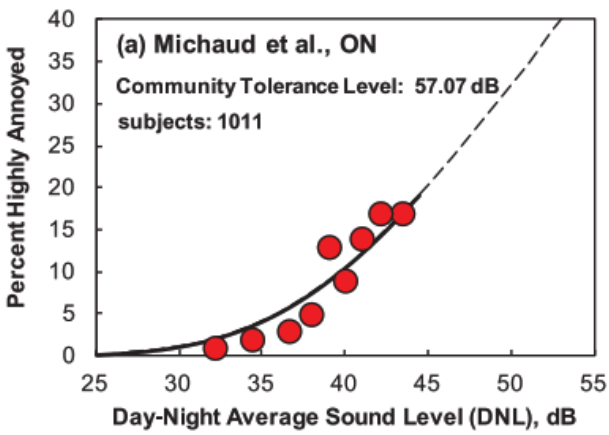

Fig 2 Variation of Wind Turbine annoyance with level

The equivalent curves for wind turbines are not as highly developed as for transportation noise (Fig.1). An example from Michaud is shown in Fig. 2 (Michaud *et al.*, 2016). Here the 10% highly annoyed level is at about 40dB DNL, compared with 60dB DNL for transportation noises.

2. Interaction of residents and wind turbines

The distress and ill health which is reported in the vicinity of some wind turbines is primarily attributed to noise, but visual effects and electromagnetic radiation are other potential contributors. Affected persons are not passive recipients and any reaction to the turbine can be interpreted as sending a response back to the turbine. This response will vary, depending on how residents relate to the wind turbine. If they believe the turbine is the source of their problems, affected persons may send a distress response. Others may feel that the turbine is a beautiful construction, which they enjoy looking at. The physical input, which comes from the turbine, produces an emotional output, such as annoyance, pleasure or indifference. Provision of a telephone complaint line may enable the emotional response to be converted into action.

Fig 3 illustrates these effects, where in addition to interactions with the wind turbine, residents may also be subject to ongoing influences, which act to modify their response. These influences include interventions from objector groups or individuals, negative press reports e.g. on infrasound and general "fright factors".(Deignan *et al.*, 2013), which may have influenced the listener prior to installation of the turbine.

Residents who experience extreme responses are outside standard noise dose concepts, reacting intensely to very low levels of noise.

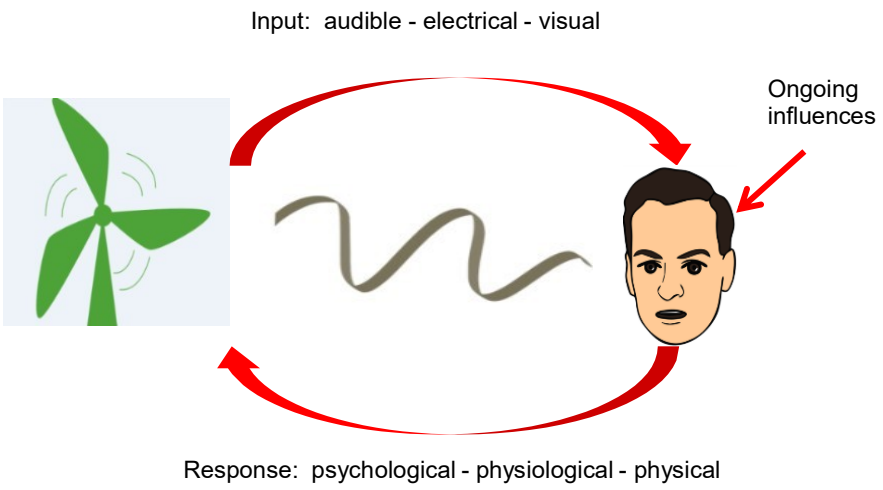

Fig 3 Wind turbine and listener interaction

3. Wind Turbines, Annoyance and Health

A number of reviews of effects of wind turbines on health were published round about 2010 but, as these largely used the same information, they came to similar conclusions. However, recent reviews, using wider and updated sources, have come to comparable conclusions to the earlier reviews. For example

> "This joint statement……summarizes the results of the best research available and concludes that there is little scientific evidence that sound from wind turbines represents a risk to human health among neighboring residents." (Thorne *et al.*, 2019)

Summaries of annoyance from wind turbines and effects on sleep and health, which have been published in recent years include:

Personal and situational variables associated with wind turbine noise annoyance (Michaud et al., 2016)

Before–after field study of effects of wind turbine noise on polysomnographic sleep parameters (Jalali et al., 2016)

A review of the possible perceptual and physiological effects of wind turbine noise (Carlile et al., 2018)

Pregnancy exposure to wind turbine noise and adverse birth outcomes: a nationwide cohort study (Poulsen et al., 2018)

Response to Noise Emitted by Wind Farms in People Living in Nearby Areas (Pawlaczyk-Luszczynska et al., 2018)

Variables associated with wind turbine noise annoyance and sleep disturbance (Radun et al., 2019)

Wind turbines and health (Thorne et al., 2019)

Health effects of wind turbines on humans in residential settings: Results of a scoping review (Freiberg et al., 2019a)

The influence of wind turbine visibility on the health of local residents: a systematic review (Freiberg et al., 2019b)

Impact of long term exposure to wind turbine noise on redemption of sleep medication and antidepressants. a nationwide cohort study (Poulsen et al., 2019a)

Long term exposure to wind turbine noise and risk for myocardial infarction and stroke: a nationwide cohort study (Poulsen et al., 2019b)

This selection from papers in the current literature illustrates the interest in the topic of wind farms and health.

4. Extreme responses

The widespread use of “annoyance” to describe an effect of wind turbines is unsatisfactory, as a single word does not express the multiple reactions which commence with awareness of the (impending) presence of the turbines, through auditory and visual stimuli, and potential progression to some highly stressed residents who claim that their life is disrupted by the turbines. Only a small number exhibit this extreme response, becoming highly annoyed by low noise levels. These are the small number of residents at the lower end of the response curve (Figs 1 and 2). Their response may be contributed to by other stimuli, in addition to turbine noise. (Blanes-Vidal and Schwartz, 2016) Extreme responders may not respond according to a noise dose relation, but are distressed by any perception of the turbines.

5. Managing Change

There is a parallel between the reactions of some people to wind turbines and the stages of grief, as experienced by a person who has been given a limited time to live, or a person who has lost a close family member. These stages were described by Kübler-Ross. (Kubler-Ross, 1973) , The Stages concept has been supported by later work (Holland and Neimeyer, 2010) and has been successfully applied to a range of areas in which it has become necessary to manage change in one’s personal or professional life (Dyer, 1994). In this respect, Kübler-Ross applies to the personal adjustments required to adapt to a change in environment caused by introduction of wind turbines.

Kübler-Ross (Kubler-Ross, 1973) identified five stages of adaptation response, as in Fig 4:

1. Denial
2. Anger
3. Bargaining (which we will change to Negotiation)
4. Depression
5. Acceptance

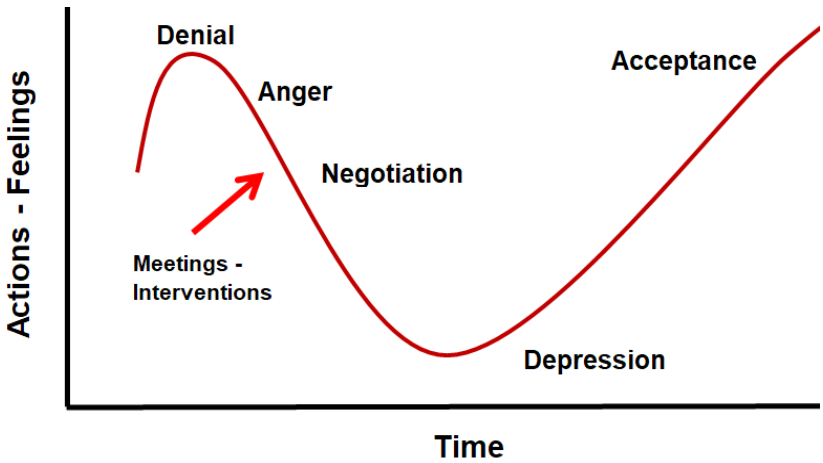

Fig.4 Kübler-Ross stages of adaptation

Consider a situation in which residents first hear that a wind farm is proposed in their locality. Some may welcome the proposal, others may be indifferent, but some may declare strong opposition. The first reaction of opponents is often **Denial** – it can’t be true, they

can't do this to us. Confirmation of the proposal leads to **Anger** and resentment, whilst plans are developed to challenge the decision. This leads to the **Negotiation** phase, during which there are public meetings, discussions with the wind farm developer, local authorities etc. The public meetings are often very heated and used by objectors to spread misinformation about turbines, whilst developers try to be reassuring.. Following negotiation, some of the residents who oppose the wind farm may suffer from **Depression**, feeling that there is no solution to the problem. Eventually they may come to **Acceptance** when they understand that they cannot stop the windfarm.

Those who exhibit high annoyance at low sound levels are the most likely to remain in the **Depression** stage.

Not everybody follows these five stages in sequence and some may move both forward and back within them, but they are a useful guide to understanding and managing an unwelcome change in our lives.

During the Anger and Negotiation stages, there will be local meetings, with interventions by people from outside the district, who wish to share their experiences. This may be a time of misinformation when illusory truths, for example on infrasound, proliferate (Leventhall, 2017) and susceptible residents are pushed further into depression, from which they are unable to escape. Some of these long-term depressed residents may exhibit physical symptoms, such as tension and poor sleep quality. They respond negatively to the presence of the turbines, and any indication of turbine operation is a trigger for distress. "I can still hear it and it's making me ill"

Alternatively, Negotiation can lead to a resolution of problems and enable the residents to feel that they have been consulted and listened to, that they are part of the process. Exclusion of residents from critical decision-making fosters opposition, whilst inclusion may lead to acceptance. The residents want to genuinely feel that they have been able to influence the outcome of the Negotiation phase. (Maris *et al.*, 2007) (Walker and Baxter, 2017) (Firestone *et al.*, 2018)

The most affected residents can be compared to "HUM Sufferers", who are distressed by sounds which cannot be measured or traced (Leventhall *et al.*, 2003) (Bommer *et al.*, 2016) (Frosch, 2016). A recent example is described in

https://www.leicestermercury.co.uk/news/uk-world-news/pensioner-says-neighbours-noise-driving-2668121

Wind turbine complainants and Hum complainants show much commonality. In both cases the symptoms relate to the listener's high stress levels, rather than direct physiological effects of a low level of noise. The symptoms of Wind Turbine

Syndrome (Pierpont, 2009) and Noise Stress (Leventhall 2002) (Nagai *et al.*, 1989; Møller and Lydolf, 2002) are compared in Table 1. The symptoms are seen to be very similar, demonstrating the Wind Turbine Syndrome as an example of stress from exposure to an unwanted noise. It is necessary to consider the paths by which the stress may develop. A controlling factor is a listener's attitude to the noise source – their mindset. Attitudes are malleable and may be conditioned by external influences, leading to an Illusory Truth[1] (Leventhall, 2017), whilst resentment is a very corrosive influence.

WTSyndrome (Pierpont)	**NOISE STRESS (e.g. the HUM)**
sleep disturbance headache ear pressure tinnitus dizziness vertigo nausea visual blurring tachycardia irritability problems with concentration and memory - panic episodes associated with sensations of internal pulsation or quivering "which arise while awake or asleep"	Insomnia headache pressure in ears or head dizziness nausea eye strain fatigue distraction nose bleed feels vibration muscle spasms palpitations skin burning stress tension etc.

Table 1 Comparison of noise stress from Wind Turbine Syndrome and other Sources

6. Misophonia and noise sensitivity

It may be difficult to distinguish between two persons, exposed to the same noise, when one is believed to be highly noise-sensitive and the other is believed to suffer from misophonia, which is a strong, acquired aversion to certain trigger sounds.

Noise sensitive people generally have a latency in their response, but are upset by continuous sounds of the type they find irritating.

The misophonic person is averse to specific trigger sounds, and has developed a learned, fast response to these. That is, there was an earlier time when the person responded normally to the sound, but the sound subsequently developed a specific trigger meaning, leading to misophonia. A characteristic of misophonia is that the misophonic response is fast and associated with both an emotional and physical

[1] Illusory Truths arise, for example, following repetition of a false statement until it becomes accepted through familiarity

response, such as uncontrolled muscle tightening, at the start of the exposure. (Edelstein *et al.*, 2013; Cavanna and Seri, 2015; Kumar *et al.*, 2017) . Whilst anger is the main resoponse associated with misophonia, the related phonophobia elicits fear of the sound.(Palumbo *et al.*, 2018) Both exhibit physical responses.

A low level of noise trigger is sufficient to stimulate a misophonic response. The trigger may develop to include other sounds, if these become associated with the original trigger. The misophonic person must avoid their trigger sound and take steps to prevent its association with additional sounds, so that these do not become independent triggers.

Application of misphonia concepts to wind turbine noise indicates a possibility that a small number of extreme responders may be exhibiting a learned misophonic reaction. Onset of misophonia is mainly amongst younger people, but the older are not immune and there is the potential of misophonia developing, particularly in some who were initially antagonistic to wind turbines. Residents with misophonic reactions to wind turbine noise are in a difficult situation, as they cannot easily remove themselves from the trigger noise, other than by changing location. Some do this.

7. Infrasound

Infrasound has a special place in discussions on wind turbine noise. Its adoption by objectors led to presention and misrepresentation as a “fright factor” and its supposed effects have become a firmly established illusory truth (Leventhall, 2017). Much of the evidence that has been put forward by objectors to support their claims that infrasound is harmful is taken from work at considerably higher infrasound levels than those from wind turbines. For example, Punch and James describe work at high levels as relevant, by implication, to the low levels from wind turbines.(Punch and James, 2016).

Current attitudes to infrasound were driven by the Wind Turbine Syndrome (WTS) (Pierpont, 2009), such that those who claim adverse affects from turbines are described as Wind Turbine Syndrome sufferers. The Wind Turbine Syndrome is said to be caused by an affect of infrasound from wind turbines on the vestibular and related systems in the body, but is not supported by scientific evidence. One scientific paper claims support for WTS, but the paper (Schomer *et al.*, 2015), although published in a well-known refereed journal, is clearly flawed, as can be seen as follows.

Schomer et al assume that the effects on the otolith, which is part of the balance system within the inner ear, are similar for both whole body vibration and for infrasound exposure and, after some calculations on the mechanics of the otolith, reach the conclusion that a 0.7Hz tone at 54 dB (0.01Pa) produces about the same to three times the force on the otolith as is caused by a 5m/s^2 vertical, whole body acceleration at the same frequency. In this, the 0.7Hz tone is assumed to be a wind

turbine blade pass frequency, whilst the $5m/s^2$ is related to US Navy criteria for nauseogenic effects. (Kennedy *et al.*, 1987).

Schomer et al are proposing that greater potential for nauseogenic effects occur from airborne 0.7Hz at 54dB (0.01Pa) than from a $5m/s^2$ whole body vertical acceleration at the same frequency. Developing this a step further ($d=a/\omega^2$) shows that the vertical displacement produced by the vibration is about 0.25m. A vertical displacement of 0.25m corresponds to a pressure change of 3Pa (hρg) or 104dB, which is considerably greater than that from the wind turbine. It is unlikely that the infrasound from vertical displacement contributes to nausea, since nausea also occurs from horizontal vibration, where there is no change in vertical height. (Golding, 2001). Thus, it appears that the nausea from vertical vibration is due to the effects of whole body movement, not infrasound. Consequently, Schomer et al have not shown that infrasound, at the levels from wind turbines, is a cause of nausea.

Recent work has exposed the ear to high sound levels, including infrasound, detecting vestibular responses by VEMPs (vestibular-evoked myogenic potentials), which indicate excitation of the saccule.(Jurado and Marquardt, 2019) Pure tone pressures were applied to the ear via a tube sealed into the ear canal, with increasing level as the frequency reduced, reaching 132dB at 4Hz. The conclusion was that the saccule “seems to be rather insensitive to airborne infrasound”, even though the levels used were around 60dB higher than those from wind turbines.

The web site Stop These Things (STT) was set up in late 2012 as an antiwind communication and publishes a daily blog of anecdotes and pseudoscience, reprinting and commenting on press articles which attack wind energy. Infrasound is a regular topic. STT, which is published anonymously, is noted for its misrepresentations and exagerations

Some recent STT posts featuring infrasound include:

> *Home Wreckers: Finnish Study Finds Wind Turbine Infrasound Unsafe For Residents Living Within 15 Km*
> *February 1, 2019*
>
> *Pulsing Punishment: Wind Turbine Infrasound Delivers Perpetual Torment for Neighbours*
> *January 24, 2019*
>
> *‘Green’ Energy Guinea Pigs: Wind Industry’s American Victims Monitored for Infrasound Effects on Heart & Health*
> *December 10, 2018*
>
> *Silent Killer: Why Wind Turbine Infrasound Causes Serious Health Problems for Wind Farm Neighbours*
> *December 6, 2018*

Heart-stopping: German Research Finds Low-Frequency Wind Turbine Noise & Infrasound Cardiac Health Risk
November 10, 2018

And many more like these, illustrating the illusory truths with which the public has to contend.

A commonly used vehicle for spreading fears about infrasound is letters to local newspapers. A recent publication states:

> *The wind industry ignores the infrasound generated by its turbines, focusing only on audible sound. New York state goes along with this deception, overlooking the life-threatening affects of infrasound when its dangers are so extensively documented. The state's action (or inaction) is tantamount to condoning the use of residents as guinea pigs, people deprived of informed consent.*
>
> https://www.wind-watch.org/news/2019/03/25/tuning-out-infrasound-dangers/

8. Nocebo and Placebo effects

The Nocebo/Placebo effect was originally described in the medical context, where symptoms and treatments are influenced by expectations and conditioning. Recognition of the effect goes back to at least the early 1960s (Kennedy, 1961), but modern brain imaging has shown its neurological basis. (Dodd *et al.*, 2017) The outcome of communication to patients, either directly or by implication, illustrates the crucial importance of information transfer in creating expectations (Benedetti *et al.*, 2007; Bensing and Verheul, 2010; van Laarhoven *et al.*, 2011; Reicherts *et al.*, 2016; Chavarria *et al.*, 2017).

These papers make clear that the Nocebo/Placebo responses are well established in general clinical work and are powerful in their operation, an operation which is largely based on expectations and conditioning. It is a short step to consider nocebo/placebo as an element in health related responses to wind turbines, within a "background noise" of assertions that wind turbines are harmful to health.

The first direct application of the nocebo effect to wind turbines was by Chapman et al and has been supported by follow-up work (Chapman *et al.*, 2014; Crichton *et al.*, 2014a; Crichton *et al.*, 2014b; Crichton and Petrie, 2015; Tonin *et al.*, 2016; Chapman and Crichton, 2017). However, the importance of expectations was investigated earlier (Crichton *et al.*, 2013), with the following results:

> *During exposure to audible windfarm sound and infrasound, symptoms and mood were strongly influenced by the type of expectations. Negative expectation participants experienced a significant increase in symptoms and a significant deterioration in mood, while positive expectation participants*

reported a significant decrease in symptoms and a significant improvement in mood.

Chapman at al 2014 introduced the nocebo to wind turbine studies and considered the effect in a community, using submissions and publicity on a pending wind farm hearing as sources of information. Some of the media material was described as "frightening".

In addition to reviewing the literature, Crichton carried out subject-based experiments with the general outcome that subjects who have been influenced by negative expectations present more symptoms than those who have been exposed to positive expectations, as was confirmed independently by Tonin (Tonin *et al.*, 2016)

The Nocebo/Placebo are established and well documented effects in the conditioning of responses to wind turbines. Objectors are not comfortable with them because of the light they shine on objector activities. Lacking facts to counter the use of Nocebo, objectors turn to ridicule and personal attacks. For example:

> **Pierpont** *They are not fabricating these symptoms. Their symptoms are not Simon Chapman's silly "nocebo effect." The symptoms are — real! Really and truly caused by IWT infrasound.* (Pierpont, 2017)

Statements like this indicate a (deliberate?) misunderastanding of the Nocebo/Placebo effect, impying that symptoms induced by the effect are, in some way, unreal. This is not what the literature says.

Negative attitudes to wind turbines, developed through illusory truths, which are rife in the area of wind turbines, are highly likely to influence the residents' attitudes, so feeding the Nocebo effect. There is a conflict with leading objectors, who have persistently claimed a direct physiological action from wind turbines.

8. Is Help is available?

Is it possible to help severely affected residents, those in the Depression stage of Kübler-Ross, Fig.4, to live happier lives, which are not blighted by the presence of wind turbines. It has been shown that the "talking therapies", particularly Cognitive Behaviour Therapy (CBT) have promise in helping people to desensitise to a troubling noise.(Leventhall *et al.*, 2008; Leventhall *et al.*, 2012). Introductory information on CBT is given on https://www.rcpsych.ac.uk/mental-health/treatments-and-wellbeing/cognitive-behavioural-therapy-(cbt)

CBT is a form of "relaxation therapy". This is a broad term that describes a range of different therapeutic techniques. Many of these are simple, well-developed, procedures which generate a number of positive physiological and psychological benefits. The overall concept of a relaxation therapy is now well-accepted within mainstream medicine as a means of stress control and therapy is available on the

UK National Health Service. https://www.nhs.uk/conditions/stress-anxiety-depression/self-help-therapies/

CBT recognises that our thoughts, feelings and actions are connected and aims to reduce negative thoughts, so that problems are dealt with in a positive manner. CBT analyses our current problems and enables these to be dealt with positively, so reducing stress.

Relaxation is an essential part of therapy. For example, in their advice book on stress the British Medical Association, say that systematic relaxation, "Improves sleep, increases mental and physical performance, combats tiredness, decreases anxiety and tension".(Wilkinson, 2004) Essentially, it leads to a physiological and psychological state which is opposite to the state of stress, including the stress from exposure to noise.

In the application of CBT to helping noise sufferers, the first phase of the work included a group of nine participants who attended sessions over 10 weeks and were introduced to CBT concepts and techniques. Recognition of the difficulties of attending group sessions led to development as an internet-based distance learning project (Leventhall *et al.*, 2012).

Assessment, both before and after therapy, included a 25 point questionnaire (Noise Reaction Questionnaire NRQ) which explored:

- How the noise made sufferers feel (emotions)
- How it affected them physically (health)
- How it affected their daily activities and interactions with others (social)

Scoring was on a five point semantic scale

Not at all = 0
A little of the time = 1
Some of the time = 2
A good deal of the time = 3
Most of the time = 4

The results were encouraging, as shown in Fig. 5, where the main problems (highest response score) are shown by vertical dotted lines. These problems are

5 I have a hard time adjusting to the noise
9 The noise interferes with my quality of sleep
13 The noise makes it hard for me to fall asleep at night
15 The noise makes me feel agitated or restless
17 The noise makes me feel anxious
22 The noise makes me feel tired and fatigued
25 The noise prevents me from being able to relax

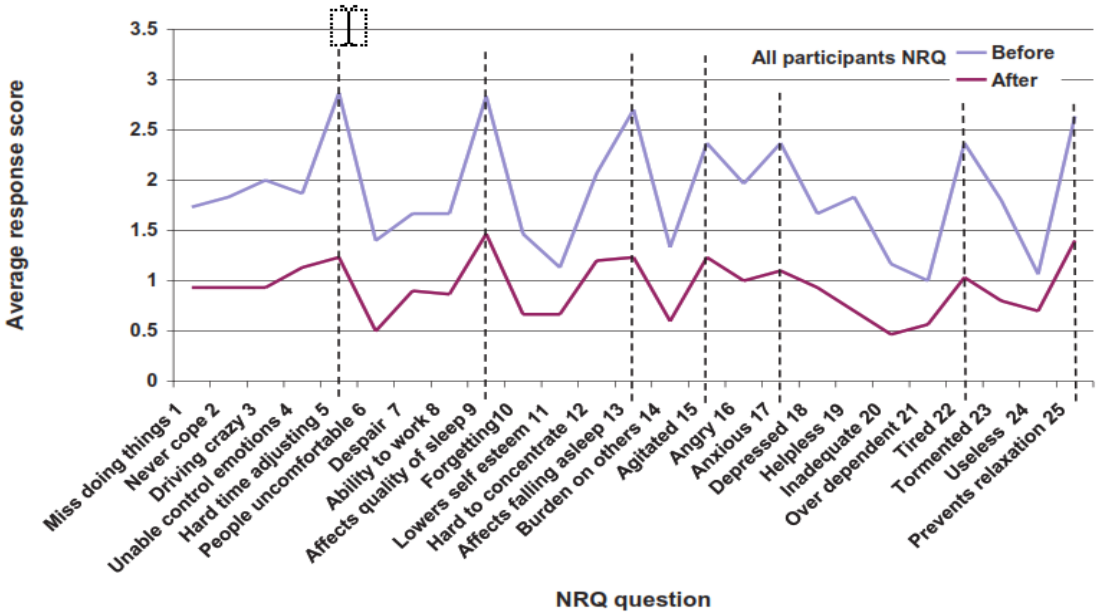

Fig 5 Before and after questionnaire responses. Averaged over subjects

The main problems are seen to be sleep/tiredness and anxiety/tension. The reduction in each of these was by 1 to 1.5 points on the five-point response scale, indicating a useful improvement in the subjects' responses.

This earlier work has shown the application of CBT to persons with noise problems and may be effective for those who have problems with wind turbine noise, but there are hurdles to be overcome. Experience with a large number of subjects showed that those who were most likely to benefit from CBT had been through all the environmental and medical processes and had failed to find the source of the noise. They were reconciled to living with their noise and were willing participants in the desensitisation process.

Another group, who believed they knew the source of the noise (often from a neighbour's property) and wanted it stopped. However, they were not always correct in their source assumption. Those who are affected by wind turbines know the source of their problems and may be reluctant to join a desensitisation program.

9. Summing up

The paper has considered those who respond acutely to nearby wind turbines, giving consideration to those who exhibit the most severe responses and have, through no fault of their own, been unable to adapt to the changes in their environment which accompany the introduction of wind turbines. Explanations for the severity of their responses are attempted, but this is a very difficult area. It is possible that severity of responses has been influenced by the strong anti-windfarm campaigns which raise fears of effects on health, but adverse effects can been rolled back by therapies such as CBT.

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