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Title: Response to Simulated Wind Farm Infrasound Including Effect of Expectation

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Summary

People living near wind farms have reported negative health effects from infrasound and attribute this to their exposure to the sound. Those exposed assert that when removed from the source of infrasound, they experience an almost immediate improvement in health. This, they say, proves the infrasound is the cause. However, there is some scientific evidence that there is no direct link between infrasound and adverse health, rather the explanation can be found in a psychosomatic response (such as a nocebo effect).

An investigation was conducted into the effect on the reported pathological symptoms of simulated infrasound produced by wind turbines. The experimental procedure closely followed that of Crichton (Crichton, F, Dodd, G, Schmid, G, Gamble, G & Petrie, K. J. 2014) except for some important differences in experimental procedure. The infrasound waveform was generated using a custom-made headphone apparatus. Volunteers were manipulated into states of either high or low expectancy of negative effects from infrasound and their reactions to either infrasound or a sham noise were recorded in a double blind experiment. A comparison is made between this study and Crichton.

It was found, at least for the short-term exposure times conducted here-in, that the simulated infrasound has no statistically significant effect on the symptoms reported by volunteers, however the state of prior concern that volunteers had about the effect of infrasound has a statistically significant influence.

1. Introduction

From the time Pierpont (Pierpont, N. 2009) coined the term “wind turbine syndrome” to describe the cluster of symptoms people experience around wind turbines (such as sleep disturbance, headache, tinnitus, nausea, vertigo etc.), there has been considerable debate in the professional literature about the topic. The view expressed by Pierpont is that low frequency noise and vibration too weak to be heard and at a level lower than the auditory threshold can still stimulate the human vestibular system potentially leading to the adverse

pathological symptoms described by those exposed to the noise. Nissenbaum (Nissenbaum, M. A, Aramini, J. J, & Hanning, C. D. 2012), by means of a social survey, concluded that people living near wind turbines in the study area had impaired mental health and suffered sleep disturbance. This was attributed to high levels of low frequency noise.

Salt (Salt, A. N, & Lichtenhan, J. T. 2014) attributes the stimulation of the ear's sensitive outer hair cells by infrasound to be the cause of symptoms. The reason given for the outer hair cells being sensitive to infrasound (even though they do not contribute to conscious hearing *per se*) is that they are displacement sensitive as a consequence of being mechanically coupled to the tectorial membrane. The long-term stimulation of the outer hair cells, according to Salt, explains the pathological symptoms observed.

Schomer (Schomer, P, Erdreich, J, Boyle, J, & Pamidighantam, P. 2013) proposes that the cause is infrasound pressure reaching the inner ear and exciting the otolith organ which normally responds to acceleration of the head. According to Schomer, the effects of motion sickness can be compared with the pathological symptoms experienced by people living near wind turbines and concludes that wind-turbine acoustic emission triggers motion sickness in those who are susceptible. Rand (Ambrose, S. E, & Rand, R. W. 2011) notes that he suffers from sea-sickness and both he and Ambrose experienced nausea, dizziness and irritability within twenty minutes of starting their noise survey of three wind turbines in Falmouth USA.

Those who disagree with these hypotheses say principally that the evidence for wind turbine noise and infrasound causing health problems is poor (Chapman, S, St George, A, Waller, K, & Cakic, V. 2013). Similarly, the Australian Government's National Health and Medical Research Council found, on review of scientific literature, that wind turbines do not pose a threat to health if planning guidelines are followed (NHMRC, 2010). Jakobsen (Jakobsen, J 2005) concludes that infrasound from modern (upwind) wind turbines can be neglected when evaluating the environmental effects of wind turbines.

Leventhall agrees and asserts there is no evidence that the low levels of infrasound from wind turbines are harmful to humans (Leventhall, G, July 2013). He concludes that the continuous infrasound levels normally produced by the inner ear in everyday situations are in the same frequency range as wind turbine infrasound and are higher in level than that produced by wind turbines (Leventhall, G, August 2013).

Turnbull (Turnbull C & Turner J, 2011) concludes that wind turbines generate infrasound well below the audibility of threshold of 85 dB(G) and at levels that are similar to those produced by other man-made sources as well as natural sources along the coast. According to Turnbull, the level of infrasound measured close to a wind turbine is prevalent in every day urban and coastal environments. The same conclusion was obtained in a study by the Environment Protection Authority in South Australia (Evans T, Cooper J, Lenchine,V. 2013).

So, in the light of such disagreement, what explanation can be provided for the

numerous psychosomatic responses reported in the literature? Crichton (Crichton, F, Dodd, G, Schmid, G, Gamble, G, & Petrie, K. J. 2014) in an experiment which manipulated the expectations of volunteers exposed to 10 minutes of infrasound and sham infrasound in a double blind experiment concluded that those volunteers, when given information about the expected physiological effect of infrasound, reported symptoms that aligned with that information. The infrasound exposure itself did not contribute to the symptomatic experience. 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. Crichton concluded that psychological expectations could explain the link between wind turbine exposure and health complaints, that is, a nocebo effect.

Chapman agrees and concludes that the reported spatio-temporal variations in complaints are consistent with psychogenic hypotheses that health problems arising are “communicated diseases” with nocebo effects likely to play an important role in the aetiology of complaints (Chapman, S, St George, A, Waller, K, & Cakic, V. 2013).

There was criticism of the Crichton experiment, most notably that the volunteers were university students, that they were subject to only 10 minutes of infrasound and the sound level of infrasound was not comparable to that measured at actual wind farm sites (Hartman R. S. 2013) (Punch J, 2013).

For this reason, the Crichton experiment was repeated by Tonin but using an experimental procedure designed to avoid those criticisms (Tonin R, Brett J & Colagiuri B, 2015 submitted for publication). The purpose of this paper is to compare the results of the Crichton and Tonin experiments and their conclusions.

2. Experimental design

2.1 Simulated Infrasound Waveform

A detailed recording and analysis of infrasound generated by wind turbines was first made by Walker at the Shirley Wind Farm in Wisconsin, USA (Walker, B, Hessler G. F, Hessler D. M, Rand R, & Schomer P, 2012). The investigation was conducted at three residences whose occupants reported health problems they attributed to infrasound. The Shirley Wind Farm consists of eight wind turbines located at varying distances from the residences, with the closest turbine being 390 m from the nearest residence.

The infrasound recorded was not random in character but was characterised by a 0.7-0.9 Hz fundamental frequency consisting of multiple harmonics, with a peak sound pressure level of 82-89.5dB with the higher sound levels measured indoors. Walker synthesized the waveform in MATLAB and produced multiple files, one of which is a 0.8 Hz trapezoidal-shaped waveform with 16 harmonics as shown in the figure below.

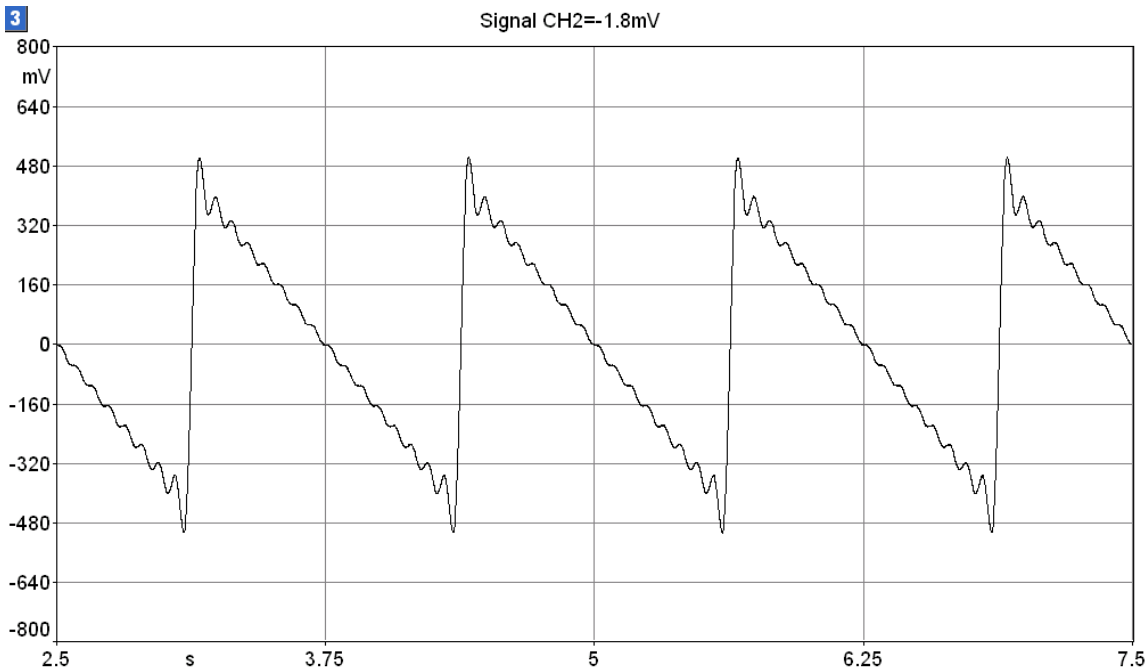

Figure 1 Infrasound signal used in experiment

In the Tonin experiment, this waveform was played at a level of 91dB peak, this being a slightly higher sound level than that recorded at Shirley. It is noted in the Crichton experiment the sound level was played at 40dB at 5Hz (the metric is not published and it is presumed the signal was sinusoidal). This was one of the criticisms by others previously noted.

2.2 Apparatus for Generating Infrasound

In the Crichton experiment, the sound level was played using a Mackie HR 150 active studio woofer. However, this speaker is not suitable for generating the low frequencies of interest for this experiment.

There are two approaches for generating sound at 0.8 Hz, one being the use of one or more large speakers to pressurise a receiving room, the other being the transduction of the sound through headphones using a pneumatic driver, each with their own advantages and disadvantages. The first approach has the advantage of being able to subject the whole body to infrasound but is not easily transportable and the experiment would need to be conducted in a quiet receiving room. The second approach has the disadvantage that only the ears are exposed to the signal but the advantage that the equipment is portable and not nearly as susceptible to outside noise. The second generating method is employed in this study and therefore there is an inherent assumption that if infrasound affects the human body, the principal path is via the ears (Møller H & Pedersen C.S, 2004).

The pneumatic generating apparatus consists of a nominal 5” diameter Visaton W 130S loudspeaker screwed airtight to the inside of the lid of Pelican Storm Case iM2075. In the centre of the lid there is fitted a 6 mm air nozzle.

The loudspeaker is driven by a DC amplifier connected to a Sinus Soundbook running SAMURAI 2.0 software which generates the electrical waveform previously described. A 200 Hz low pass filter with DC offset adjustment and a dB attenuator are connected between the Soundbook and the amplifier.

The pressure signal from the speaker is transmitted via a 1.7 m length of 6 mm inner diameter clear vinyl/polyurethane tubing incorporating a brass splitter to connect to each cup of a set of Uvex-X earmuffs as shown in the following figure. One of the cups was modified to house a G.R.A.S. 40AZ ½" Pre-polarised Free-Field Microphone connected to a G.R.A.S. Type 26CG ¼" Low Frequency CCP Preamplifier. The G.R.A.S. 40AZ microphone has a frequency response of 0.5Hz to 20 kHz (+/- 2dB) which encompasses the range of the study.

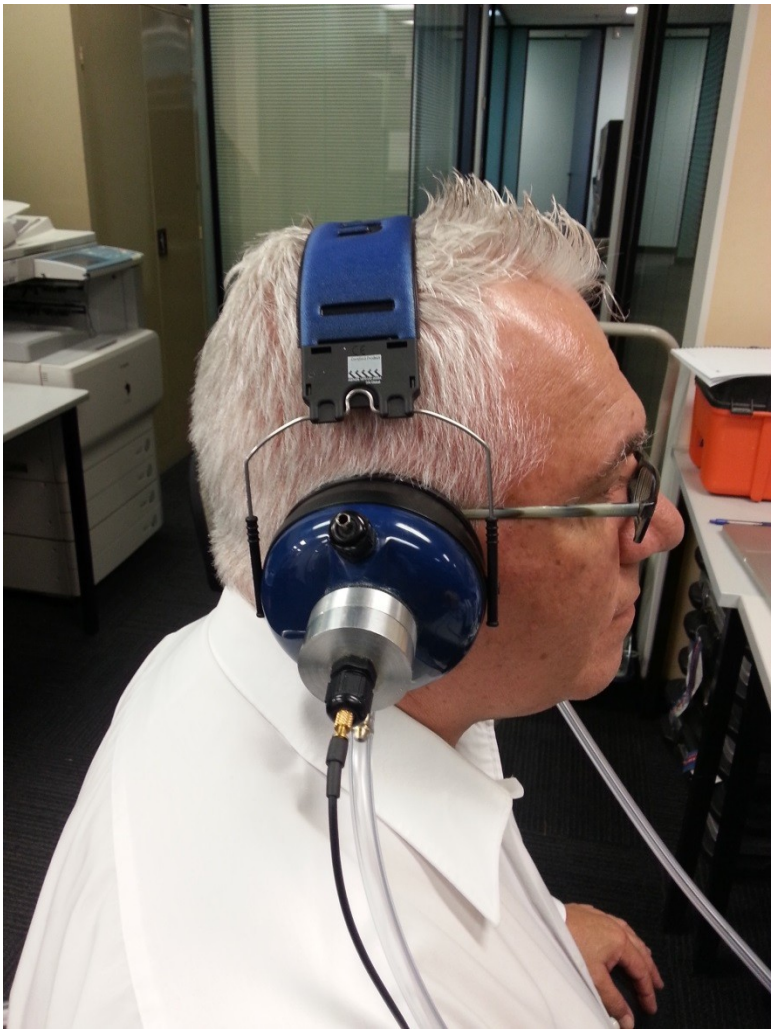

Figure 2 Complete acoustic headphones including 6mm nozzles on both ears with attached tubing, microphone and occlusion port (located just above the silver coloured microphone attachment).

An unexpected complication arose during testing of the headphones. It was

found that the measured sound level in the headphones from the heartbeat of the person wearing the headset was in the range 90 dB Peak which confounded the generated infrasound signal. The sound of one's heartbeat is audible to a person wearing earmuffs in a quiet room. The effect was reduced significantly to below 80 dB Peak by incorporating a 3 mm diameter venting port as shown in the figure above.

The source of the occluded heartbeat is thought to be pressure fluctuations from blood vessels near the surface of the skin encapsulated by the headphones, acting like a piston in a cylinder pressurising the entrapped air. Several large blood vessels, such as the external carotid artery and the superficial temporal artery, run close to the ear (Wikipedia, 2014). A detailed examination of this source of sound is beyond the scope of this study, needless to say that the sound level is reduced significantly below the 91dB Peak generated by the loudspeaker and therefore is unlikely to be a confounding factor. This was checked for each volunteer.

The following figure shows the frequency response of the loudspeaker, tubing and microphone combination with the un-occluded vents is linear within about +/- 4dB from 0.8Hz to 40Hz which comprises the frequency range of the generated infrasound and harmonics.

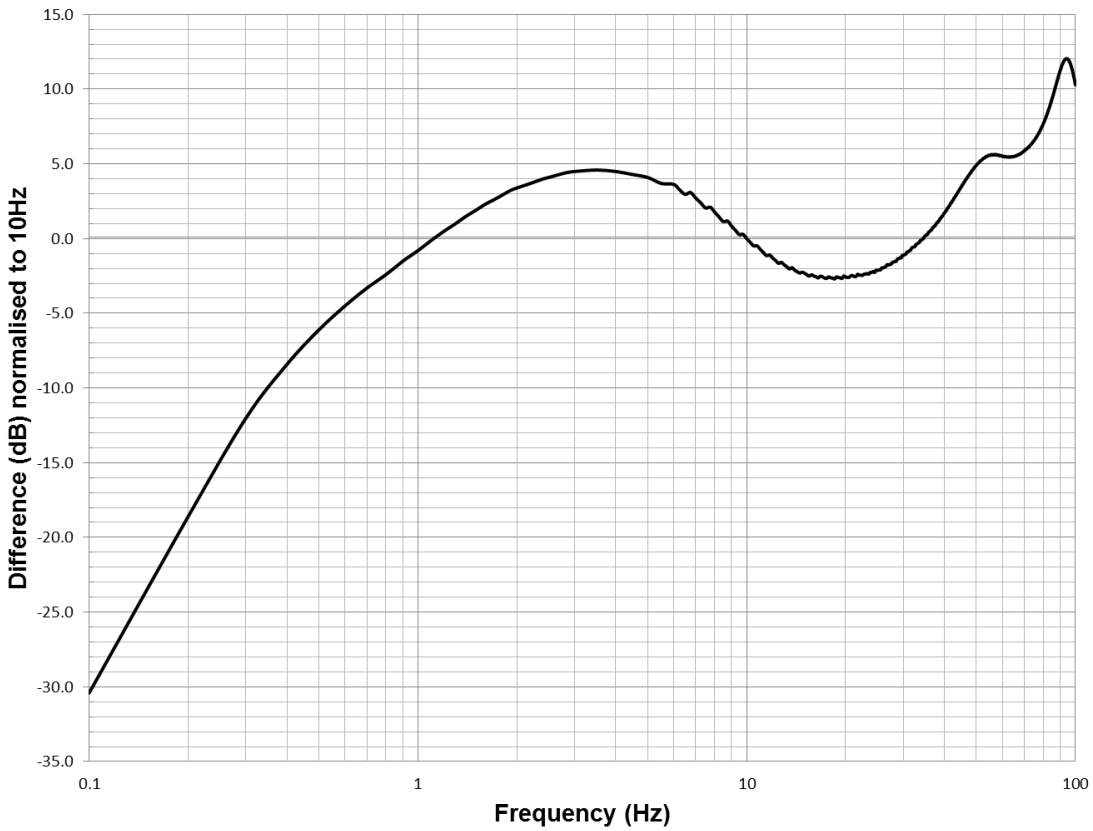

Figure 3 Headphone and Tubing Frequency Response with Attenuator Ports Open

2.3 Experimental Design

In the Crichton experiment, there were 54 university students tested, 34 women and 20 men.

In the Tonin experiment 72 volunteers were tested, 27 female and 45 male ranging in age from 17 to 82 years with a median age of 29 years. Volunteers were sourced from professional firms (not associated with wind farms), students, government organisations and family members. This wider mix in age and demographics of volunteers was intended to address one of the concerns of the Crichton experiment previously referred to.

The experiments are a double blind study subjecting the volunteers to either infrasound or no noise (sham noise) after manipulating their expectations into either high or low expectancy by using appropriate videos. Responses were recorded on identical questionnaires filled out by volunteers before and after the experiment according to the following groupings.

Table 1 Experimental Groups

	Infrasound Applied	Sham Applied
High Expectancy	Group 1 HE/ON	Group 2 HE/OFF
Low Expectancy	Group 3 LE/ON	Group 4 LE/OFF

In the Crichton experiment, the volunteers were exposed to 10 min of infrasound and 10 min of sham infrasound (no sound). In the Tonin experiment, the volunteers were exposed only once to 23 minutes of infrasound or 23 minutes of sham infrasound (but not both). As previously noted, Rand (Ambrose, S. E, & Rand, R. W. 2011) experienced nausea, dizziness and irritability within twenty minutes of starting their noise survey of three wind turbines in Falmouth USA. The selection of 23 minutes of infrasound in the Tonin experiment was intended to address one of the criticisms of the Crichton experiment previously referred to.

Prior to the test, and then again at the conclusion, the volunteers were asked to complete a questionnaire which rated to what extent they were feeling various symptoms on a 7-point Likert scale ranging from 0 (none) to 6 (extreme). There were 24 symptoms listed on the questionnaire, 12 that are typically associated with wind turbine health complaints (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 12 that are not typically associated with wind turbine health complaints (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).

Volunteers were also asked to rate how concerned they were about the health effects of wind turbine infrasound on a 7-point scale ranging from 0 (completely unconcerned) to 6 (extremely concerned).

Volunteers then watched one of two introductory videos designed to manipulate their expectations, one to heighten expectations (of an interview of wind farm affected residents explaining their symptoms) and the other to lower expectations (of an academic explaining why infrasound is not a problem). The videos may not have been the same in the Crichton and Tonin experiments however, from the description provided by Crichton, they appear to be similar.

In the Tonin experiment, at the conclusion of the expectation video, the volunteer was fitted with the special headset described previously and was directed to watch a subtitled video documentary of duration 23 minutes with no relevance to the subject matter. The examiner played either the infrasound or the sham infrasound (based on random selection) for the duration of the documentary. The examiner was unaware of which expectation video the volunteer watched nor whether the volunteer would be exposed to the infrasound until it was time to

play the infrasound or sham sound. At the conclusion of the video documentary, the volunteer completed the second questionnaire, identical to the first, without referring to the first.

In the Crichton experiment, there is no information about how the volunteers spent their 10 minutes of exposure to infrasound or sham infrasound.

The number of symptoms with a non-zero score was calculated for both the initial and final questionnaires as was the intensity of symptom score calculated as the sum of all the ratings given.

3.0 Results

3.1 Mean number of symptoms and intensity of symptoms

The results of the mean number of symptoms reported are shown in Figure 4 (total number of symptoms), Figure 5 (number of typical symptoms) and Figure 6 (number of atypical symptoms) for both the Crichton and Tonin experiments.

The results from the means are inconclusive. If the infrasound alone had a direct physiological effect it would be expected that HE/ON and LE/ON would show an increase in the number of symptoms after the experiment, while there would be little to no difference in the other two groups where there was no infrasound present. Conversely, if the infrasound had no direct effect but instead it was the expectation of harm having an effect upon their reactions (i.e. the nocebo effect), it would be expected that HE/ON and HE/OFF would show an increase in the number of symptoms after the experiment whilst there would be little to no difference in the other two groups.

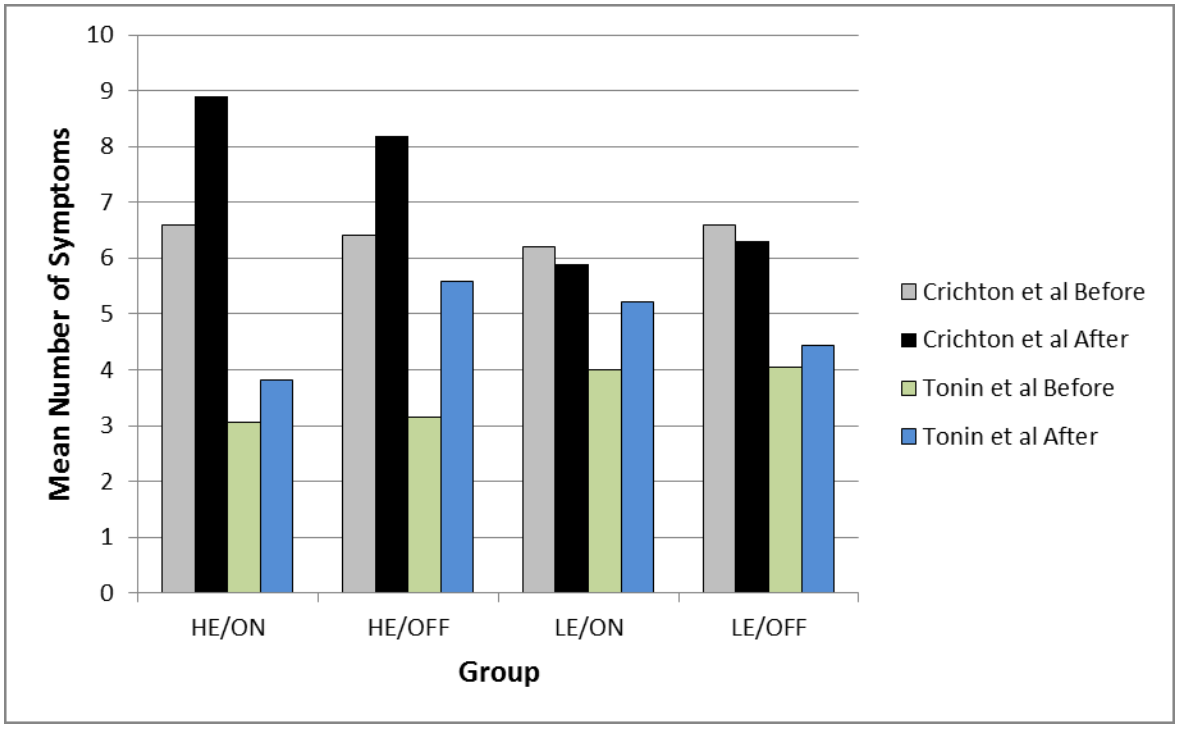

Figure 4 Mean Total Number of Symptoms Before and After per Group

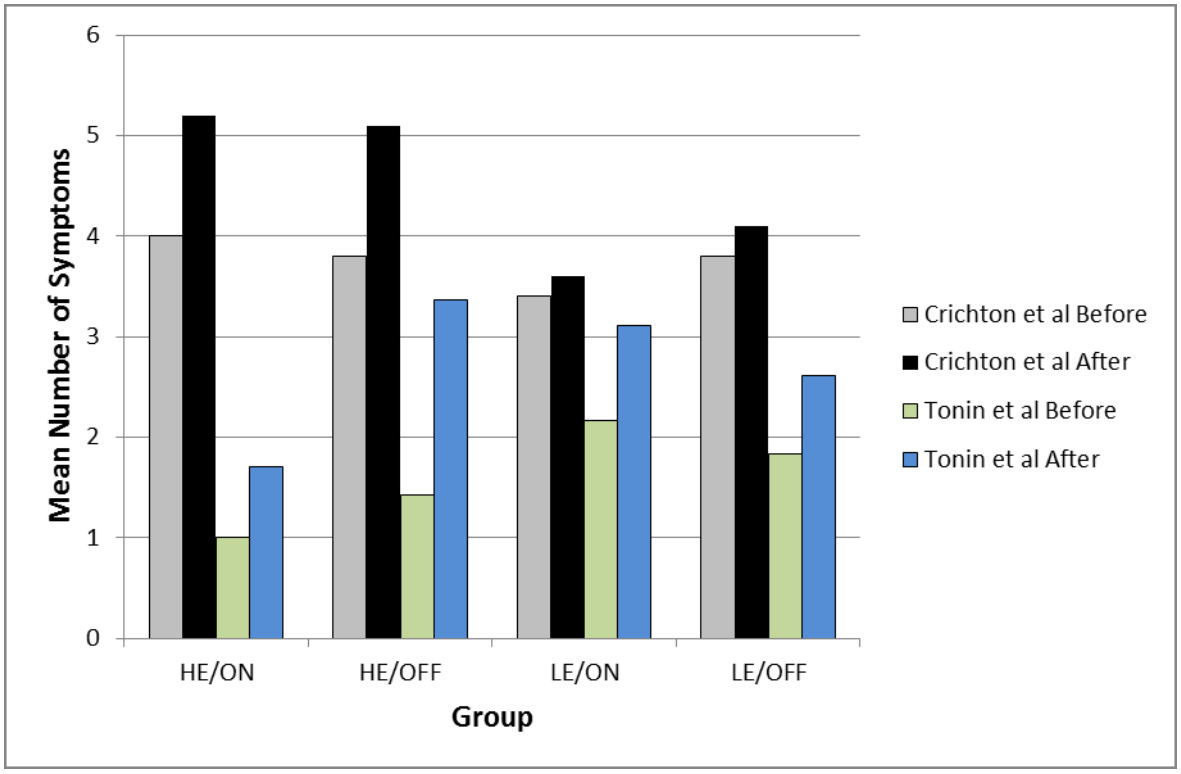

Figure 5 Mean Number of Typical Symptoms Before and After per Group

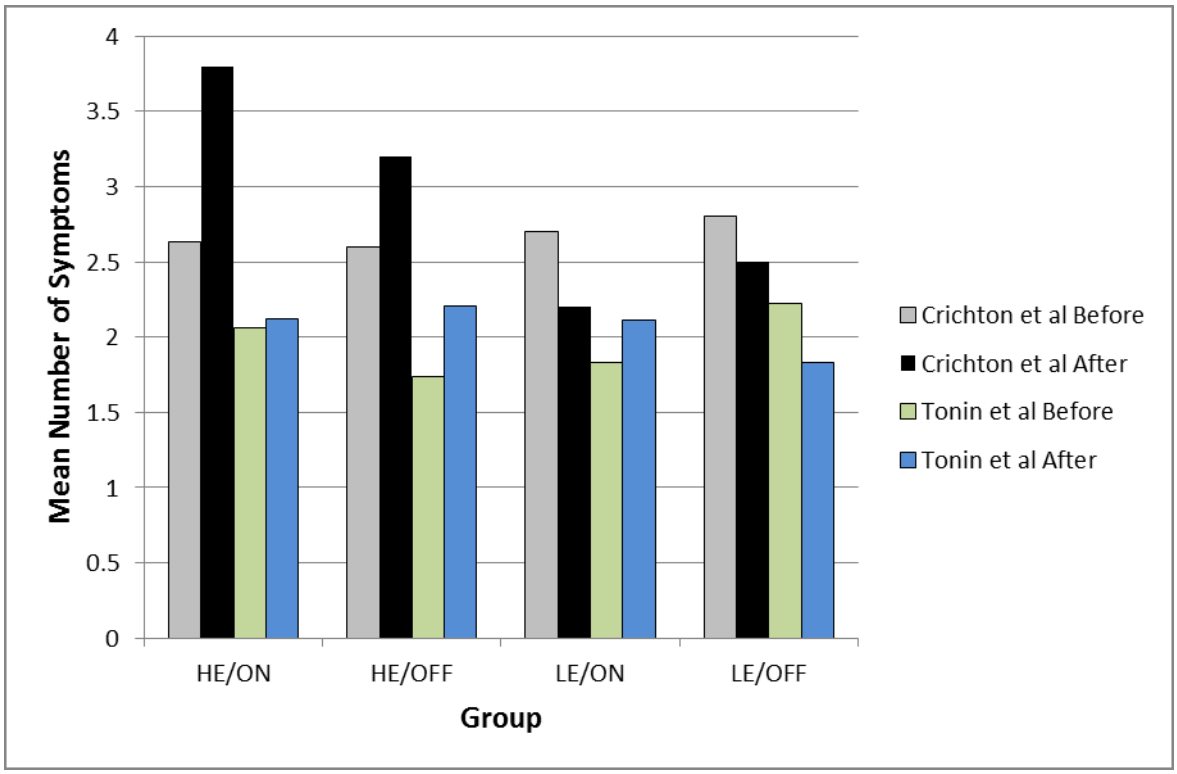

Figure 6 Mean Number of Atypical Symptoms Before and After per Group

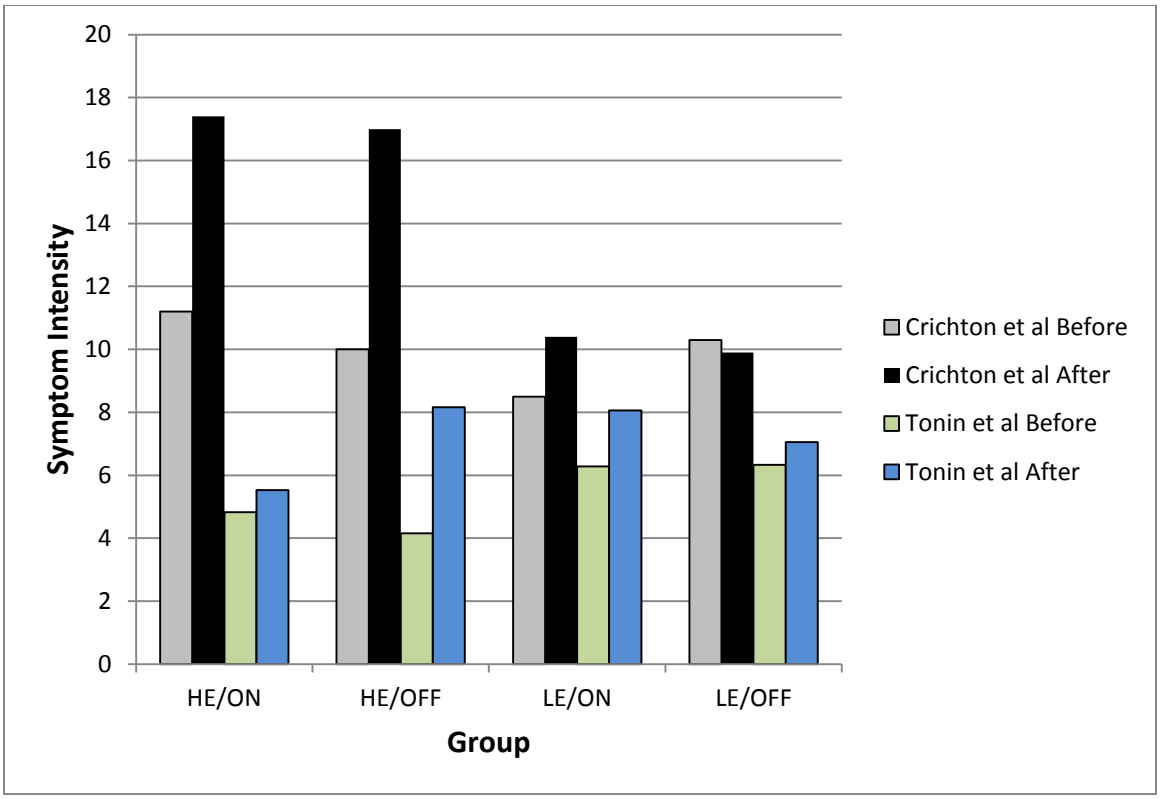

Figure 7 Mean Intensity of Symptoms Before and After per Group

A similar conclusion can be said for the mean intensity of symptoms which is shown in Figure 7. Intensity is the sum total of all the symptom ratings, for instance, if a volunteer rated headache as 2, and tiredness as 1, while all the other symptoms were rated 0, the intensity of symptoms would equal 3.

One point of difference between the two experiments is the higher number of symptoms reported in the Crichton experiment for both HE groups in both the number of symptoms and intensity of symptoms. There is no explanation for this. Nevertheless, the before and after difference in each HE group shows a similar trend.

3.1 Effect of infrasound

In the Tonin experiment, a more detailed study of the results presented above was conducted with ANCOVA analysis utilising the statistical program IBM SPSS. According to Figure 5 above, all groups experienced a net increase in the number of typical symptoms. The presence or absence of infrasound had no effect on the number of typical symptoms whereas for the high expectations groups the presence of infrasound had a negative effect $F(1, 72) = 4.02$, $p=.049$ which is statistically significant.

The Crichton experiment concluded that the effect of the expectancy group on change scores did not differ whether exposure was to sham or to infrasound. There was a significant increase from the pre-exposure assessment in the number of symptoms reported during exposure to infrasound $F(1,26)=8.16$, $p<.01$

and during exposure to sham $F(1,26)=12.16$, $p<.01$. Therefore the number of symptoms reported and the intensity of the symptoms experienced during listening sessions were not affected by exposure to infrasound. Importantly, elevated symptom reporting seen in the high-expectancy group was the same during sham and infrasound exposure.

Both experiments conclude that infrasound exposure itself did not contribute to the symptomatic experience.

3.2 Base line concern

In the Tonin experiment, the number of typical symptoms showed a statistically significant correlation with the baseline level of concern $F(1, 72) = 7.39$, $p=.008$. There is also a statistically significant correlation between the difference in intensity of typical symptoms and the baseline concern $F(1, 72) = 7.96$, $p=.006$. There is no significant correlation between the difference in intensity of atypical symptoms and the baseline concern. An ANOVA test was conducted on the baseline concern to confirm that none of the four groups had a disproportionately large mean baseline concern.

In the Crichton experiment, the influence of baseline concern was examined using mixed-model ANCOVA. The high-expectancy group was shown to be significantly more concerned $M=72.78$, $SD=18.99$ 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 controlling for baseline scores.

Both experiments conclude the influence of baseline concern as having a significant effect on the reported symptoms.

4.0 Conclusions

Despite the differences in their design, both the Crichton and Tonin experiments come to similar conclusions.

Both experiments conclude that the infrasound had no statistically significant effect on the health symptoms reported by the volunteers.

Instead, the level of concern that a volunteer felt prior to the beginning of the experiment had a more statistically significant effect on the reported typical symptoms associated with wind turbine infrasound.

It was found that the volunteers who came into the experiment with pre-conceived notions of infrasound being harmful generally reported more symptoms than volunteers who began the experiment more sceptical about the potential health impacts of infrasound. These results support the hypothesis that a nocebo effect and not a direct physiological effect may be the cause of reported symptoms.

References

Ambrose, S. E, & Rand, R. W. (2011). The Bruce McPherson Infrasound and Low Frequency Noise Study Adverse Health Effects Produced by Large

Industrial Wind Turbines Confirmed.

Chapman, S, St George, A, Waller, K, & Cakic, V. (2013). Spatio-temporal differences in the history of health and noise complaints about Australian wind farms: evidence for the psychogenic, "communicated disease" hypothesis. Pre-Publication, Sydney School of Public Health, University of Sydney.

Crichton F, Dodd G, Schmid G, Gamble G & Petrie K. J. (2014). Can Expectations Produce Symptoms from Infrasound Associated with Wind Turbines. Health Psychology, 33(4), 360-364.

Crichton F, Dodd, G, Schmid, G, Gamble, G, Cundy, T, & Petrie, K. J. (2013). The Power of Positive and Negative Expectations to Influence Reported Symptoms and Mood During Exposure to Wind Farm Sound. Health Psychology, Advance Online Publication.

Evans, T, Cooper, J, Lenchine,V. (2013). Environment Protection Authority of South Australia in conjunction with Resonate Acoustics. Infrasound levels near windfarms and in other environments.

Hartman, R. S. (2013). The Adverse Health Impacts of Industrial Wind Turbines: A Scientific Response to "It's all in your head". Zoning Board of Charlestown, Rhode Island.

Jakobsen, J (2005). Infrasound emission from wind turbines. Journal of Low Frequency Noise, Vibration and Active Control, Vol 24, No 3.

Leventhall, G (July 2013). Concerns about infrasound from wind turbines. Acoustics Today.

Leventhall, G. (August 2013). Infrasound and the ear. 5th International conference on Wind Turbine Noise. Denver.

Møller, H & Pedersen, C.S, (2004). Hearing at Low and Infrasonic Frequencies. Noise & Health 6(23).

NHMRC (2010). National Health and Medical Research Council of Australia. Wind Turbines and Health. A Rapid Review of the Evidence.

Nissenbaum, M. A, Aramini, J. J, & Hanning, C. D. (2012). Effects of Industrial Wind Turbine Noise on Sleep and Health. Noise & Health, 14(60), 237-243.

Pierpont, N. (2009). Wind Turbine Syndrome A Report on a Natural Experiment. Santa Fe: K-Selected Books.

Punch, J. (2013). Review of Crichton et al (Can expectations produce symptoms from infrasound associated with wind turbines?). Retrieved January 21, 2014, from Waubra Foundation: http://waubrafoundation.org.au/wp-content/uploads/2013/03/Review-of-Crichton-et-al.Jerry-Punch-docx.pdf

Salt, A. N, & Lichtenhan, J. T. (2014). How Does Wind Turbine Noise Affect People? Acoustics Today, 10(1), 20-29.

Schomer, P, Erdreich, J, Boyle, J, & Pamidighantam, P. (2013). A proposed theory to explain some adverse physiological effects of the infrasonic emissions

at some wind farm sites. 5th International Conference on Wind Turbine Noise. Denver.

Tonin, R, Brett, J & Colagiuri, B (2015 submitted for publication). The Effect of Infrasound and Negative Expectations to Adverse Pathological Symptoms from Wind Farms. Submitted for publication to Journal of Low Frequency Noise, Vibration and Active Control, January 2015.

Turnbull, C, Turner, J. (2011). Measurement of Infrasound from Wind Turbines and Other Sources. Fourth International Meeting on Wind Turbine Noise, Rome Italy 12-14 April 2011.

Walker, B, Hessler, G. F, Hessler, D. M, Rand, R, & Schomer, P. (2012). A Cooperative Measurement Survey and Analysis of Low Frequency and Infrasound at the Shirley Wind Farm in Brown County, Wisconsin. Public Service Commission of Wisconsin.

Wikipedia. (2014). Common Carotid Artery. Retrieved March 7, 2014, from Wikipedia: http://en.wikipedia.org/wiki/Common_carotid_artery