The Impact of Long-Term Infrasound Exposure on Cognitive Performance

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A. Specific Aims

This experiment will serve as a preliminary study of the effect on cognitive performance, if any, of long-term exposure to infrasound. Cognitive performance will be operationally defined as the composite score on the CDR computerized assessment system. While data on animal and human exposure to infrasound in the short-term have been accumulating for decades, recent controversy regarding wind farms have predicated a need for studies in long-term exposure.

Two experimental variables will be introduced: frequency of exposure (6, 12, and 18 Hz) and intensity of exposure (50, 60, and 70 dB), with a control (non-exposure) group. The design will be independent-groups, pretest-posttest 3x3 crossed factorial design with 3 participants per condition, ages 18+, in each group and a 3-person control group (N=30). The only limitation placed on participants is that they test normal for their age group in hearing, according to an audiologist. Participants will perform the CDR system to establish baseline cognitive performance, then tested again after the assigned experimental condition.

It is predicted that a lowering of frequency and increase in intensity of exposure over the course of 7 days will produce an increasingly pronounced lowering of cognitive performance.

B. Introduction

Infrasound has been a contentious subject of research since its explication in the 1970s. At that time, studies mostly dismissed the idea that infrasound that could not be consciously perceived could be harmful to humans (Harris & Johnson, 1978). However, with the advent of wind farms across the western world, infrasound has again come under investigation.

Infrasound is loosely defined to be sound that is below the human threshold of hearing, below approximately 20 Hz (Leventhall, 2007). Though the definition appears straightforward, the situation is slightly more complicated than that. Studies have demonstrated that frequencies below 20 Hz, down to ~2 Hz, can be consciously perceived if the intensity of the sound is great enough (Leventhall, 2007). There are two parameters of the infrasound, then, that need to be considered: frequency (measured in Hz) and intensity (measured in dB).

Infrasound has been implicated in physical illness (Chrichton et al., 2013, Farboud et al., 2013, Salt & Huller, 2010), sonic weaponry (Leventhall, 2007), and even experiences of the paranormal (French et al., 2009, Parsons, 2012). The potential sources of these low frequencies can be natural, such as earthquakes, storms, and waves in large bodies of water (Leventhall, 2007), or they can be manmade, such as factory machinery, farm equipment, or large windmills. This suggests that infrasound is all around us all the time, so what is the reason for experimenting on the impact of exposure?

It is the windmills that have rekindled an interest in infrasound studies. A number of people who live near the recently constructed wind farms have reported symptoms of "wind turbine syndrome" (defined below) (Chrichton et al., 2013, Farboud et al., 2013, Salt & Huller, 2010), while others claim that there is no perceivable sound or pressure waves coming from the windmills, and that the symptoms are caused by something else or are even imaginary (see the editorial section of any press article regarding infrasound and wind farms).

The claims that the symptoms are imaginary are spurred by the fact that, in general, one cannot consciously "hear" infrasound. That is, if the intensity is low enough that the pressure waves in the air do not excite the hair cells in the ear, the sound is inaudible (Dommes et al., 2009). However, the pressure waves still exist, and can act on the inner ear and vestibular system (Dommes et al., 2009), the eyeballs (Parsons, 2012), and, if the intensity is great enough, on the body as a whole (Leventhall, 2007). Some suspect that this impact on the body spurs the symptoms of "wind turbine syndrome."

"Wind turbine syndrome" is really an unofficial collection of symptoms including headache, nausea, chest pain, heart arrhythmia, and other physical symptoms that some people claim are caused by long-term exposure to the low frequencies generated by infrasonic equipment. The precise causal mechanisms are unclear, but infrasound is a potential candidate for these symptoms (Farboud et al., 2013).

While infrasound has been defined and studied for almost fifty years, those experiments all take place in very controlled and short-term situations. Clinical studies have examined the effects of infrasound on various cellular-level components of the inner and outer ear of both lab animals and humans (Dommes et al., 2009, Hensel et al., 2007, Spyraki et al., 1978, Mariana, 2007). Some experiments have examined the effects of short bursts of infrasound on the cognitive abilities of lab animals and humans (Harris & Johnson, 1978, Harris et al., 1976, Liu et al., 2010, McKillop et al., 1994, Petounis et al., 1977), but the findings of those studies are difficult to generalize to the case of a person living or working in the presence of constant infrasound. Tellingly, the last paragraph of almost every infrasonic experiment in the recent literature has a line that reads something like "Unfortunately, no studies have been conducted addressing the effects of long-term exposure to infrasound…"

This experiment, then, will address just that issue. The experiment is intentionally broad and takes place outside of the laboratory. The results are meant to be suggestive; to spur more interest and hopefully more resources into studying infrasound in the environment and the impacts of long-term exposure. The impact of these sorts of studies will have implications not only for the wind energy industry, but for any person or organization concerned with industrial safety and noise pollution.

The reason for addressing cognitive performance impact as opposed to physiological measures is to address the possible damaging effects in terms of human behavior and pathology, as opposed to discrete systems within the animal or human nervous system. An experimental effect on cognitive functioning would be something that could be reported to the general public or to interested institutions in terms that they could easily identify with, as opposed to reports on specific protein synthesis or the action of a particular cochlear cell.

C. Method

This experiment will use an independent-groups, test-retest 3x3 factorial design. There are two independent variables – frequency and intensity. Each possible combination of three different frequencies (6 Hz, 12 Hz, and 18 Hz) and 3 decibel levels (50 dB, 60 dB, and 70 dB) will be tested making six total experimental conditions (see the following table).

6 Hz 50 dB	6 Hz 60 dB	6 Hz 70 dB
12 Hz 50 dB	12 Hz 60 dB	12 Hz 70 dB
18 Hz 50 dB	18 Hz 60 dB	18 Hz 70 dB

Each condition will be tested using three participants. There will also be a three-person control group against which the experimental results for each condition can be measured. This brings the total number to 30 participants. The participants' age will be limited by the age of consent (18), with no upper age limit. Eligible participants will be chosen from a list of volunteers (in the order they volunteered in) and assigned to an experimental/control condition by raffle. Volunteers will be acquired by advertising through classified ads and online advertisements in as many neutral venues as necessary (private newspapers, campus newspapers, Craigslist, etc.). It will be desirable for the participants to live as far apart as possible, within a three-hour drive from the lab, to control for possible geographic phenomena. Compensation will be offered in the amount of $10.00 per day of participation. IRB approval will be obtained prior to advertisement.

Once contacted via phone or email, the researcher and a licensed audiologist will drive to the participant's home. The participant will be informed of the exact procedure and possible short-term health problems associated with infrasound exposure to both animals and humans and will be required to sign an informed consent form.

After consent is obtained, the participant will be subjected to a basic battery of hearing tests by the audiologist. This will establish that the participant's hearing is functioning at an average level for their age, to control for possible effects of pre-established hearing loss or damage.

The participant will then be asked to perform the CDR battery of tests. This pretest will establish a baseline performance of cognitive functioning to be compared to following the experimental condition. Time of day will be noted.

In each experimental condition, the participants will be asked to keep the apparatus (continuously active) in their home over the course of 168 hours (7 full days). The experimenter will assemble the apparatus in a room that is most central and where it will be least obtrusive. The participant will be instructed to ignore the apparatus as best as possible, and to not touch it under any unexceptional circumstances. The experimenter will then set the frequency and decibel level and activate the speaker.

The apparatus will be made up of three components: a sine-tone generator (Gwinstek GFG-8020H Function Generator), a signal amplifier (PylePro PT 3300 Hybrid Amplifier), and a 16-inch Peavey speaker in wood casing. The decibel level will be read with a Radio Shack Digital Sound Level Meter.

The only deception involved in this experiment is introduced at this point: the apparatuses in the control conditions will not be active. They will appear identical in that the lights will come on the signal generator and amplifier, but false wires will be connected to the speaker so that no current actually flows. Because the infrasound will be set below audible threshold in each condition, the participant will have no way to know whether the speaker is activate or not. In the control condition, the experimenter will mime the action of testing the decibel level with the sound level meter.

The experimenter will then instruct the participant to go about their lives as normal for the next seven days and confirm the follow-up appointment seven days from then. The experimenter will then leave and no further contact will be made for the seven days.

Following the seven days, the researcher will return to the participant's home and ask them to perform the CDR system battery again, at the exact same time of day as the initial test. No further information will be gathered from the participant, as it is expected that the number of participants in each group will account for any personal differences in behavior/sleep/diet/etc., over the course of the thirty-six hours. Referral to the audiologist will be given if requested. The experimenter can then debrief the participant, answering any question the participant might have and explaining the reasoning behind the experiment. Finally, the experimenter will pack up the apparatus and return to the lab to report the findings.

To control for external conditions such as weather or outdoor activity level but keep costs reasonable, the conditions will be run 3 at a time during the summer, for a total of four weeks.

D. Expected Results and Alternative Outcomes

Because this is a crossed factorial design, an investigation of the correlations between each experimental condition and the control group scores will yield evidence of an effect. Specifically, the researcher will be looking for an interaction between frequency and decibel level on participants' performance on the CDR system. An F-test will be performed on the differences in scores from pretest to posttest for each experimental condition versus the control group. Then, those correlations can be compared by examining the differences in differences to determine if one experimental condition was most powerful. *p* will be set at <0.05, as it is a kind of pilot experiment and any evidence of an effect should be noted.

The experimenter predicts that a decrease in frequency and an increase in intensity will result in the most pronounced decrease in performance on the CDR battery. Thus, the lowest frequency at the highest intensity should produce the largest decrease in score from pretest to posttest. If the results were laid out in the format of the above table, the difference in scores should increase as one moves rightward and downward on the table.

The null hypothesis of this experiment would state that long-term exposure to the infrasound at any infrasonic frequency or intensity value used in this experiment has no effect on cognitive performance. This would mean that none of the scores changed from pretest to posttest in any statistically significant way.

If the null hypothesis is rejected, possible alternative explanations are readily available, especially because the experiment is taking place outside of a laboratory setting and over such a long period of time.

One type of threat that could occur over the duration of the experiment is a history threat. Perhaps something geological occurs that impacts the cognitive performance of the participants. Unfortunately, the experiment is geographically limited to a reasonable driving distance from the lab, so if a magnetic or weather-related phenomenon occurs, it would likely affect all participants. A large-scale disturbing event might also be detrimental to peoples' test-taking, such as a terrorist attack or natural disaster.

However, the most likely alternative explanation is a reaction effect. The experiment is fairly explicit in its design, and the participants will likely guess the nature of the data the experimenter is collecting. If the participants have read materials on the wind farm debate, they will likely already have an opinion regarding the effects of long-term infrasound exposure. This could, and likely would, influence their performance on the CDR battery, with people wanting to believe there is an effect performing worse than they might otherwise and vice-versa.

It is believed, however, that confounding variables due to time, geography, or participant belief is adequately controlled for by use of a fairly large N and a control group. If an effect is demonstrated, future experiments will want to begin isolating variables more specifically related to those possible confounds.

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