INFRASOUND AND ITS EFFECTS ON HUMANS

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ABSTRACT

This paper explains what infrasound is and the importance it has in the behavior of humans that come in contact with it. Review of some literature is presented in order to understand the different sources that produce this phenomenon. Physiological effects of low frequencies are shown as well as some of the uses that mankind is giving to this lower part of the frequency spectrum. Limitations to exposure are presented briefly in order to understand that this subject needs further research. A small experiment is conducted and reported in order to observe the effects of infrasound on humans. This experiment is then compared to a similar example.

1. INTRODUCTION

Infrasonic sound or infrasound is the sound produced below audible frequency range. Audible noise is determined to be between 20 Hz and 20000 Hz. Even though the threshold of hearing is set at 20 Hz, this does not mean that humans are incapable of listening to and perceiving sounds below this frequency. For the same reason infrasound can not be mistaken to be an inaudible noise. Humans are capable of hearing frequencies down to 1 Hz with high enough sound pressure [1]. Infrasound is a pressure variation between 0.1 and 20 Hz [2].

During the 1970´s infrasound was a fairly popular topic within the scientific community. In spite of the loss of interest over the years, recently it has been gaining importance. Wars have brought new technology to the battle field making military scientific research on new types of weapons and ways to avoid attacks from enemies more attractive. Doctors and psychologist have been interested in trying to understand the effects of low frequencies on the natural resonances of the organs of the human body. Musicians and artists have been exploring new experimental ways to express their art evoking the idea of feeling and immersive-ness instead of mere listening experiences.

Generation of infrasound can be found everywhere on the planet. It is therefore important to acknowledge some of the sources that produce it. To this information some explanation of the unusual physiological responses of the body can be linked, and perhaps some previously unexplained sensations can be related to this phenomenon.

To understand better the impact on humans that infrasound has, a subjective experiment is presented. The results are merely concerning physiological responses and are compared to a similar test done by several professionals in areas related to the subject.

2. GENERATION OF INFRASOUND

Infrasound is determined to be the lowest part of the frequency spectrum (figure 1.) characterized by the frequencies below 20 Hz [3]. But why is it important, that we care about a noise that according to the threshold of human hearing can not be heard?

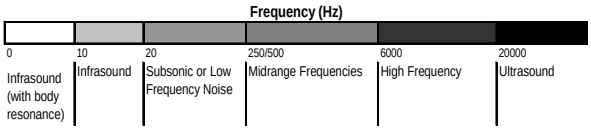


Figure 1. *Frequency spectrum with the specific ranges of frequencies for each qualification [4],[5],[6].*

First of all it is important to clarify that misconception; if the pressure is high enough the threshold of human hearing can be spread over a broader range [5] and infrasound can be perceived. Although lower frequencies are harder to produce, infrasound can be related to natural phenomena such as earthquakes, winds, thunder, volcanoes, waterfalls and ocean waves among others [7],[8]. It can also be produced by machines and household appliances or transportation vehicles such as trains, automobiles, aircrafts and rockets [7],[8]. Humans themselves are responsible for some infrasound as we run, swim or even whisper into someone's ear [5]. But as long as the pressure levels of these frequencies are low enough we do not to realize that we coexist with them. Table 1 shows some examples of infrasound sources and their correspondent sound pressure levels.

Also, infrasonic sound can be found in blast wave weapons where the second zone of the explosion, made up of the sonic wave destroys everything that it touches, since it has a huge momentum and high amounts of pressure. In this case the infrasound is not affecting the human body as a mere frequency, but as a resonator that couples with the natural resonances of the internal organs [9].[i]

Another important source of infrasound in our world is animals. We are not aware of it because we don't hear them, but some of them rely on low frequencies to communicate. Elephants and whales are among some of those that produce infrasonic sounds that travel incredibly long distances. In the case of the whale, this powerful range of frequencies is also used as a hunting weapon. "It has been known that certain whales are able to stun their pray with powerful blasts of inaudible sounds. Called "gunshots", whales focus these powerful blasts at large squid and other fish to paralyze and capture them. In some instances, they have been known to burst their pray apart by tonal projection alone" [9].

Source	Est Frequency	Est Sound pressure level (SPL)
Geophysical	< 0.01-10	54-104
Thunder at 1Km	< 4-125	<114
Earthquake	< 1	
Ocean Waves	< 1	
Wind: 100Km/hr	< 1	135
25Km/hr	< 1	110
Atmospheric Pressure Fluctuations	< 1	100
Volcano	< 1	
Running	< 2	95
Swimming	< 2	140
Diving to 2m of water	-1	180
Blow into another's ear	< 0.5	170
Industry	5-100	70-110
Diesel Engines	10-20	110
Wind turbine, 150m downwind	2-10	80
Ventilation/air conditioning	1-20	60-90
Jet Engines	1-20	135
Jet engine (underneath flight path at airport)	10-sev.1000	135
Jet engine with after burner (at runway margin)	20-800	148
Sonic booms	1-100	120-160
Ship engine room		133
Blast wave	< 1-100	unlimited
Aircraft	<10	120
Submarines	5-10	140
Large rocket, crew compartment	10-2000	135
Larrge rocket at 1.6Km	1-200	130
Helicopters	5-20	130
In car (windows closed)	5-100	100
In car (windows open)	1-30	120
Loudspeaker headset	1-200	146
Whole-body chamber, loudspeakers	2-100	140
Whole-body chamber, piston	0.5-10/30	172/158

Table 1: *Some infrasound sources with their respective frequency range and estimated sound pressure level [5],[10].*

3. SOME USES OF INFRASOUND

As was mentioned before, infrasound had a rising period of interest over the 70's that did not last long, although, the development of newer technology in the last few decades has been raising questions again about this topic leading to new areas of research.

3.1. Weapons

Humanity became more conscious and aware of the importance of Non-Lethal Weapons (NLW) after losing several lives with the testing of devastating weapons. This weaponry is in constant evolution and military researchers are using all the technology available in the world to improve it every year [11]. However it can not be said that acoustic weapons are a novelty, they have been around since ancient times. Examples of them can be found even in the Bible (the walls of Jericho) [12], in WWII where supposedly Hitler's army tested and used them [13], and recently in the US during the Los Angeles AIDS riots and in the siege of the Branch Davidian Cult in Waco, Texas [14]. Although some of this has not been proven, rumors have been growing.

At present, infrasonic non-lethal weapons are mainly thought to be used against rioters without causing permanent damage. As tests have shown (Table 2), infrasound is a great source to provoke physiological discomfort and therefore make raging people reduce the anger.

The idea of an infrasound weapon was developed in the 20th century by the French scientist Vladimir Gavreau. After accidental exposure to infrasound [15], Gavreau developed and tested several types of sound weapons including extremely long and wide pipes that were able to produce extremely low frequencies. According to some literature the effects were almost devastating and really successful in terms of harm done, but secrecy has been maintained and authenticity of these weapons has not been found.

Some examples of infrasonic weaponry that some people have been "quietly" talking about are:

- "Sophar": non lethal high power acoustic radiator used for riot suppression [16].
- "Squawk box": supposedly build and tested in Ireland by the British army, but existence denied by the ministry of defense. The main idea is to create a 2 Hz frequency using the combination of two high tones (16 KHz and 16.002 KHz) [16],[1].
- Infrasound room: a building can work as a helmoltz resonator if infrasound is played through the ventilation ducts [12].
- Vortex ring generators: they use several impact pulses near the resonant frequency of the human body via a standard grenade launcher previously converted into a vortex generator [12].
- "Curdler": annoying shrieking sound below the threshold of pain played at different intervals is believed to create a sound barrier and demolish enemy structures [1],[17].
- High power beam created by an explosive-driven pulser or a piston by forcing air into tubes. Researched by ARDEC (Army Armament Research, Development and Engineering Centre) [1].
- "Device propelling a baseball-sized acoustic pulse of about 10 Hz over hundred of metres, scalable up to lethal levels" [1].
- Acoustic blaster [16].

However, it is difficult to know if this so-called infrasound acoustic NLW exists or at least can be created. How can we tell if it is not just an invention?

Since military secrecy is so important in the world that we live in, it is hard to tell what is true and what is not. Conspiracy

theories, secret weapons, torture methods, etc. will be always withheld from the public eye. The only way to determine if these infrasound weapons are viable or feasible to construct, and if they work as well as is cited, is reliant on the scarce information given by military journals and the scientific research that physicists such as Doctor Jürgen Altmann have made.

The first thing that it is important to notice about generators of infrasonic sound or noise is that they have to be powerful enough to produce high SPL's (sound pressure levels) at low frequencies. This is not easy to do with regular voice-coil loudspeakers; only 1%-2% of energy is used in these devices, in order to improve the efficiency to 10%-50% rear loaded horn loudspeakers have to be used. An alternate method is to use whistles and sirens, which can raise the effectiveness by up to 70% and can go well into infrasound frequencies. Basically they act as a resonant cavity with a mouth (like an organ pipe) and as a variable frequency single tone producer using, for example, combustion engines [14],[1].

Practicality is the next issue to take into account. To acquire the necessary power to produce the signal, the sound source must have a minimum length of 1m [12],[5] so to carry these Non Lethal Weapons a helicopter or big vehicle (truck) would be needed [5]. Also directionality becomes an issue, the large wavelengths of infrasound (λ=17m and above) spread in all directions and are really hard to focus [7]. This is one of the major problems since police forces or weapon users may be exposed as well as rioters.

An important characteristic of today's armaments is the efficacy of weapons at long distances, lowering the risk of soldier's lives; infrasound weapons lack this property. Infrasonic acoustic waves suffer from geometric divergence as their main attenuation factor, making the weapons effective for only a few hundred meters [12]. To overcome this problem authors such as Roman Vinokur have proposed the use of robot drones to carry the weapon and lower the risk of the troops.

3.2. Arts and music

Infrasound is also used nowadays by modern composers such as Matt Heckert to produce a more sensitized music. By creating a "Mechanical Sound Orchestra" with instruments such as the resonator (figure 2) he intends to make people feel the music rather than just hear it. As the San Francisco chronicles describes it "…his music makes air throb against the wall and against your skin." [18]. In this case, the use of technology and mechanical machines is summed together to create a different experience for the audience, but infrasound can also be heard from classical instruments such as the organ or the trombone. The largest organ in the world is located in Atlantic City with a pipe of 64 feet, nine inches long (19.7932m) generating a tone of 8 Hz that is felt rather than heard [19].

Brian "Lustmord" Williams is another example of this type of experimental music. Instead of using machines as Heckert does, Lustmord plays with field recordings made in caves or crypts and mixes them with tibetan horns and ritualistic incantations, exploring sensations of rumbles [20].[ii]

But infrasound is not only important in art exhibitions and contemporary compositions; regular music also holds an important content of infrasonic sounds that should be played through a faithful system. A CD survey to demonstrate this important issue was performed by Louis D. Fielder and Eric M. Benjamin from Dolby Laboratories Inc. and Pinkerton Control Systems Corp. respectively [21]. The results showed that lower spectral content is present in a large variety of CDs and therefore a better subwoofer reproduction system should be guaranteed. For this reason, advanced technology has been developed to create more powerful subwoofers that are capable of reproducing these low frequencies. Some of their data can be seen in table 2.

Figure 2. *Matt Heckert's resonator. One of the instruments of the mechanical sound orchestra. http://www.mattheckert.com/MSO/Resonator.html*

As seen in table 2 these infrasonic components can be encountered in movie soundtracks as well, here the use of infrasound is related to horror films as well as action and science-fiction movies among others, with the intention to make the auditoria feel what people call "goosebumps". Some motion pictures examples using low-frequency sounds are: "Cronos" [22] or "Irréversible" among others [23].

Frequency		Composer	Selection
120 dB	110 dB		
10	12,5	Tschaikowsky	1812 Overture
16,5	16,5	Dupre	Symphony in G Minor
15	17,5	Grofe	Grand Canyon Suite
18	18	Hindemith	Organ Sonata #1
18,5	18,5	Jongen	Symphony Concertante
12,5	22	Flim & the BB's	Big Notes
16,5	22	Strauss	Also Sprach Zarathustra
22	22	Bach	Kyries, Gott heiliger Geist
24	24	Saint Saëns	Symphony #3
25	25	Williams	Star Wars Theme
19	25	Bach	Toccata & Fugue in D Minor
29	29	Bill Cobham	Warning
29	29	Various	Movie soundtrack "Country"

Table 2: *Some examples of compact discs with frequencies below 32 Hz [21].*

3.3. Comprehensive Nuclear Test Ban Treaty (CTBT)

Another use of infrasound in the last 20 years has been to monitor the illegal use of nuclear weapons. On November 24 1996, 71 countries got together in the United States and signed a treaty which prohibited all nuclear test explosions [24]. At present day 177 countries (states) are members of the treaty and 138 have ratified. In order to monitor these nuclear activities around the world, 377 monitoring stations have been located at different places.

The monitoring can be seismic, hydroacoustic, infrasonic, or radionuclide. 11 hydroacoustics stations scattered among 4 continents (North America, Latin America, Europe, and Australia) deal with the detection of shock waves traveling under water. 60 infrasound stations are responsible for the

detection of very low frequency sounds in the atmosphere created by natural or man made phenomena. These noises are sensed by arrays of 4-8 microbarograph sensors located 1-3 Km apart. An International Data Centre located in Vienna receives the information from each station in real time, processes it and sends bulletins of events detected to the countries in the treaty. The most important job of each infrasound station is to determine and distinguish the source of infrasound as natural or man made signals [25],[24]. Since this technology is fairly new, stations have been in charge of characterizing and determining the way different signals from specific sources appear in the sensors data. The 60 infrasound stations are distributed thus:

- South America →8
- North America →9
- Europe → 14
- Africa →9
- Asia → 11
- Oceania →8
- To Be Determined → 1

3.4. Other uses of infrasound

Some medical uses for infrasonic frequencies can be encountered; most of them deal with the fact that they affect blood pressure and therefore can heal patients with circulation disorders. In the Netherlands the company Inframed Medical Equipment promoted the SonoMat which is an instrument capable of breaking up arterial blockages [7]. Also some sound therapy devices can be found such as the QGM Infratonic. These hand held instruments produce signals between 7.83 to 13.5 Hz using infrasonic sound transducers in order to improve lymphatic circulation, and help with the relaxation of the muscles and the nervous system [26],[7].

Finally, even though it is not directly a way to use infrasound, it is important to mention that some scientists have associated paranormal encounters in haunted places with infrasonic sounds. Vic Tandy in his articles "Ghost in the Machine" [27] and "Something in the Cellar" [28] attributes the frightening sensations and visions within these places to low frequency signals that resonate with body organs; specially the eye causing nystagmus responses.

4. INFRASOUND AND THE HUMAN BODY

So far ways to generate infrasound and its different uses have been discussed but nothing has been mentioned about the effects that these infrasonic signals have on the human body and suitable limits of exposure to them.

4.1. Effects of exposure to infrasonic sound

Since human organs have resonant frequencies in the lower range of the spectrum, infrasound affects the body in several ways. To determine the symptoms that this noise induces on humans, several experiments have been conducted giving similar results. In order to create and manipulate infrasound in a controlled environment, pressure chambers were used. These specialized rooms were built in order to do some of the testing, enclosing the subjects. Normally infrasound was played through several loudspeakers (six 0.46m diameter loudspeakers on either side of the chamber) or hydraulic driven pistons (1.83m and 46cm) [8],[16]. Table 3 shows some effects of LF at specific frequencies and SPL's from experiments.

(1) Frequency range 2-5Hz: SPL range 100-125dB
(a) Movement of the eardrum in response to the pressure changes
(b) Pressure build-up in the middle ear
(c) Difficulty in swallowing, all subjects were persistently trying to swallow as a mechanism for pressure release
(d) Slight post-exposure headaches which were not persistent
(2) Frequency range 2-5Hz: SPL range 125-137.5dB
(a) Movement of the eardrum
(b) Difficulty in speaking and voice modulation
(c) Chest wall vibration
(d) Swaying sensations as if falling
(e) Lethargy and drowsiness
(f) Slight tinnitus at frequencies above 10Hz
(g) Post-exposure headaches and fatigue
(3) Frequency range 5-15Hz: SPL range 125-137.5dB
(a) Movement of the eardrum
(b) Middle ear pain
(c) Difficulty in speaking and voice modulation
(d) Severe chest wall vibration
(e) Severe abdomen vibration and associated feelings of nausea
(f) Falling sensations
(g) Lack of concentration and drowsiness
(h) Tinnitus
(i) Severe post-exposure fatigue and headaches
(4) Frequency range 15-20Hz: SPL range 125-137.5dB
(a) Severe middle ear pain
(b) Respiratory difficulties-gagging sensations. In one case spasms of uncontrollable coughing developed
(c) Nasal cavity vibration
(d) Persistent eye watering
(e) Tinnitus
(f) All subjects experienced sensations of fear including excessive perspiration and shivering, these symptoms decreased with successive exposures
(g) Severe post-exposure fatigue and headaches
(h) In two cases (both female) cutaneous flushing

Table 3: *Some examples of symptoms sensed by subjects exposed to infrasound at specific frequencies and sound pressure levels [8].*

Before mentioning some of the general symptoms associated with infrasonic noise it is important to note that everybody reacts different to the stimuli, depending on age, contexture and several other factors, so some results can be anomalous [12],[5].

Annoyance is one of the most common results of exposure to infrasound, it can be described as "a feeling of displeasure evoked by a noise" or "any feeling of resentment, displeasure, discomfort and irritation occurring when a noise intrudes into someone's thoughts and moods or interfere with activity" [4]. Nausea is another effect evoked by the presence of these low signals (normally 16 Hz), the intensity of this symptom depends on the sound pressure level at which it is played; some experiments and researches have mentioned people vomiting [7],[16]. Low frequencies affect the inner ear (vestibular system,) and some forms of vertigo, imbalance or motion sickness can be felt. As medical uses of infrasound have indicated infrasonic sound is closely related to blood pressure;

in the 6-16 Hz region at levels of 95-130 dB in an exposure time of one hour, diastolic pressure increases can be detected as well as systolic blood pressure and pulse rate decreases [7].

With the use of EEGs (Electroencephalograms) it has been possible to determine some decreases in wakefulness with exposure to low frequency signals 10 dB above the hearing threshold in the 6-16 Hz range [4]. Inaudible frequencies with enough SPL are felt rather than heard, leading to a direct coupling of the sound and the body creating feelings of anxiety [14]. Last but not least some research papers talk about the presence of results are contradictory and vary too much to assure that it is a specific effect [29], also the different resonant frequencies of the eye found in different literature, makes it even harder to prove. These and other physiological responses to infrasound are considered an acoustic attack [14] and therefore isolation and rest periods are recommended after long or intense exposures.

Altmann in his studies explores the relationship of vibration of the human body with infrasound, by the simple principle of resonance. Also the difference in dimension of the large waves compared to human bodies makes him explore the idea of pressure "At low frequencies where the body dimensions are smaller than the wavelength (2m for frequencies below 170 Hz), the same momentary pressure applies everywhere, and the tissue behaves as a viscoelastic fluid with much lower compressibility than air" [1]. To give some idea of the resonance of some body parts, table 4 shows different information found in several papers. It is important to recall that for the same body part different frequencies are found in the literature.

Frequency	Body part	Effect	References
Below 2 Hz	Whole body	Moves as a whole	[14]
7 Hz	Body's organs	Organ rupture	[12]
5 Hz	Whole body	Main resonance, greatest discomfort is caused	[14]
4-6Hz	All organs	In phase movements of all organs in the abdominal cavitiy with consquent variation of lung volume and chest wall.	[14]
0.5-100Hz	All organs	Whole body vibration on health activities and comfort	[16]
4 Hz	Head	resonance	[4]
2-20Hz	Head	resonance causing general discomfort	[15]
10-20Hz	Throat	Voice may warble	[14],[16]
15-60Hz	Eyes	Blurred vision	[14]
1-100Hz, mostly above 8Hz and strongly 20-70Hz	Eye balls	Difficulty in seeing	[15]
40-60	Lungs	the inner pressure counteracts the chest wall and abdomen movements	[14]

Table 4: *Some examples of resonance frequencies for some body parts [8].*

4.2. Limits of exposure

Since infrasound has been considered inaudible for so many years, there are no regulations on the limit of exposure to it as an international standard [10]. To be able to talk about restrictions it is important to determine safety hearing thresholds. For audible sounds among medium and high frequencies, levels of 120 dB start to cause discomfort in the ear and pain arises with levels up to approximately 140 dB, going higher to 160 dB can result in the rupturing of the eardrum [14].

Infrasound, as said before, can be generated by machines or even by standing waves in long "tube" shape rooms, factories, industrial control rooms, etc., therefore workers are most affected by it.

Due to the low levels of these infrasound frequencies in the environment described above, feeling the wave becomes an important issue. In some cases, the normal complaint that workers would have in these sorts of places would be fatigue and tiredness, annoyance or some sort of discomfort that disappears as soon as the sound has stopped, and lower performance in mentally demanding tasks [4],[30]. Since lower frequencies do not affect everyone in the same way, and A weighted being a poor measurement of low frequencies that underestimates the effects caused by these noises [4],[31], it is really hard to tell what level should be recommended for the lower part of the frequency spectrum. Some standards are found in Poland, PN-N-013307:1994 [30], or Sweden: estimation curve SOSFS 1996:7/E, for example. More research in this area is needed to determine an international standard of the maximum levels that workers can be exposed to infrasound. Also the creation of protection for these people is required since earmuffs and earplugs do not offer the adequate protection at low frequencies, and can enhance the infrasonic noise experienced [7],[1]. A recommended exposure limit of eight minutes of noise at 150 dB per day is suggested in exposures of up to 7 Hz, for 7 Hz to 12 Hz 145 dB is recommended and 140 dB for frequencies from 12-20 Hz [32].

5. PHYSIOLOGICAL EXPERIMENT

Experiments with infrasound have been carried around the world, most of them in order to gather information of body frequency resonances and discomfort. In this case two similar experiments will be discussed with the idea of gathering some information of changes in emotion between stimuli with and without infrasound.

5.1. Silent music

On the 31st of May 2003 a group of engineers, artists, musicians, and physiologists, decided to carry out a physiological experiment of infrasound effects on people through music. With the sponsorship of the National Physical Laboratory (NPL) of the UK they organized 2 concerts at the Purcell Room in London where infrasound tones were played to the audience laced with contemporary musical pieces. The idea was to introduce the infrasonic sound (fundamental frequency of 17 Hz) in one of the musical pieces without letting the audience know that it was there.

With the aid of questionnaires, data was collected during the concert concerning demographic, background, and physiological information [34]. To determine the emotions of the audience, the questionnaire asked their feelings before and after the pieces in order to detect any changes between the musical sections. Two of the pieces contained infrasound while the remaining 4 did not.

Results showed unusual experiences most of all related with emotional and physiological responses such as anxiety, headache nausea, and increase in heart beat among others [34]. Even though the percentage of people detecting correctly the infrasound stimuli in each piece was higher than the percentage not detecting it, the difference is not markedly high. As people were aware of the stimuli being played, unusual sensations were felt during pieces with no stimuli.[iii]

5.2. Comparable experiment

In order to test the effects of infrasound at low pressure levels on people, an experiment was performed for this paper at The University of Sydney's surround sound studio in the Faculty of Architecture, Wilkinson Building.

5.2.1. Method

Eleven subjects were asked into the studio to answer a questionnaire while listening to an unknown CD of jazz music [35]. The questionnaire (Appendix A) was divided into 3 different sections; the first consisting of general demographical and physiological information followed by an emotional scale similar to that used in the London experiment (Happy-Sad, Aroused-Sleepy, Excited-Bored, Angry-Calm) from 5-1, and a brief logic test which consisted of unscrambling a number sequence and a letter sequence. This logic test was included in order to determine if decrease in task performance was present in a short exposure to infrasound. At this stage of the test the music was played through the front left and front right Tannoy speakers of the room, with no infrasonic stimuli present.

The second section of the test was performed after introducing a frequency of 19 Hz played through 2 Whise subwoofers hidden behind the curtains of the surround sound studio. Music and infrasound were played at the same time, letting the subjects know that some sort of stimulus was present but not exactly what it was. In figure 3 a comparison of the levels between the music itself and the music plus the infrasound stimuli is shown.

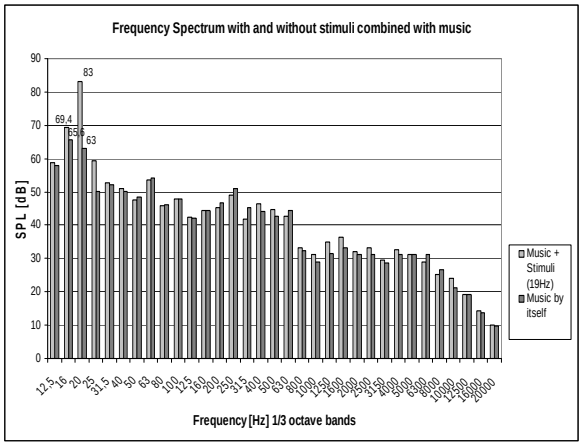


Figure 4. *Level comparison between the test signals with and without the 19 Hz stimuli.*

After 10 minutes of just listening to the signals combined, 10 physiological questions were presented as well as the same emotional scale of the first part of the test, and a similar logic test. To determine the decrease or increase on performance, time of commencement of the logic test was recorded as well as time of completion recorded.

The third section consisted of the jazz music with no infrasound stimuli. Just as in the second part, subjects were aware of the absence of the unknown stimuli. In this part concrete questions were asked that gave information on what differences they felt between the sections of the test, and if unusual sensations were experienced. An emotional scale was presented again in order to compare subjects' emotions at each stage. Figure 4 shows the comparison in levels of just the 19 Hz stimuli with the background noise of the room (Surround Sound Studio).

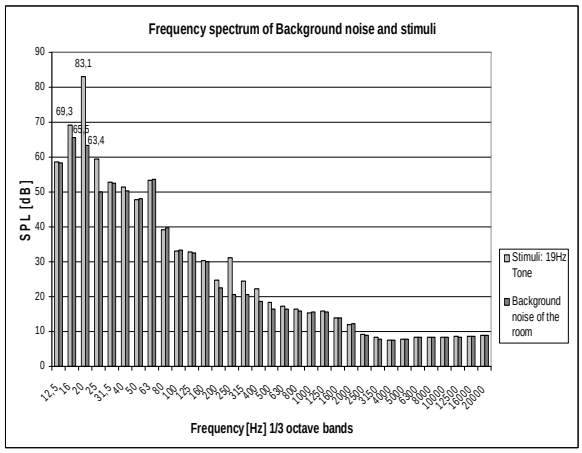
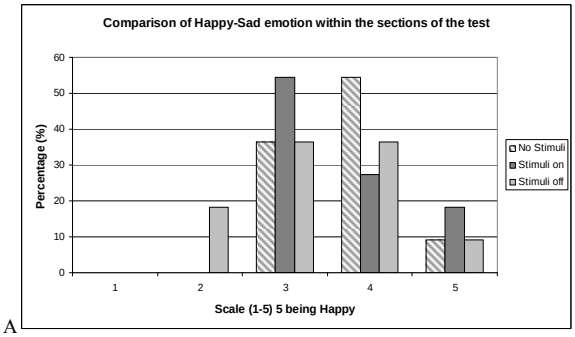


Figure 4. *Level comparison between the background noise of the room and the infrasound 19 Hz tone.*

5.2.2. Results

Similarly to the results in the silent music experiment, where dissimilarity in the different sections was expected, the emotion scale does not show a particular trend. The only specific change can be seen in the happy-sad scale where 55% of the subjects changed from being quite happy/quite sad (3 on scale form 5-1) without stimuli, to being less happy (2 on the scale) when the stimuli was on (figure 5A).



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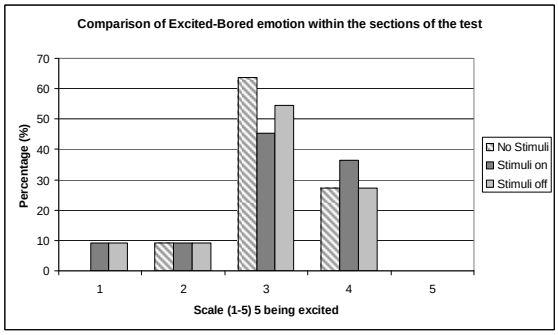

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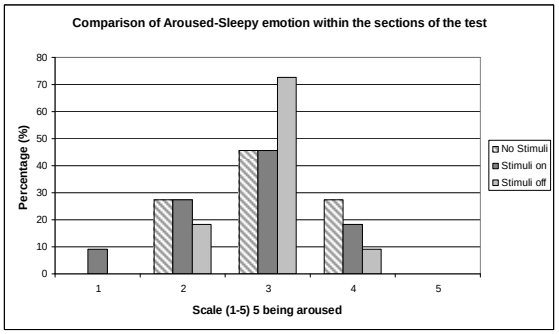

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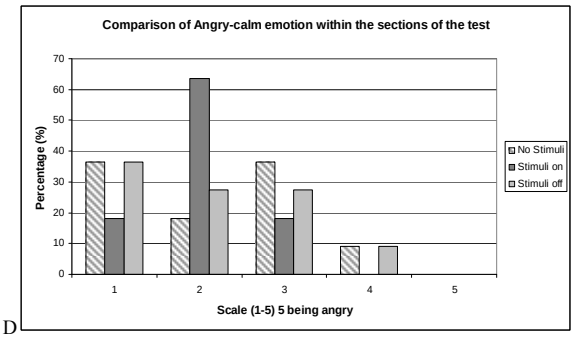

D

Figure 5. *Emotion scale comparison during the different sections of the test. A. Happy-Sad Scale comparison. B. Excited-Bored scale comparison. C. Aroused Sleepy.*

On the Excited-Bored scale (figure 5B) when there was no stimuli present 63.6% of the population felt in-between the emotions (3 in scale). When the stimuli was on, the emotion scattered around the scale (1-5), but when it was off again 55% of the subjects tended to return to the original emotion (3 in scale). On the aroused-bored emotion scale (figure 5C), scattered results were observed when the stimulus was not present and when the stimulus was on, but when the stimulus was finally off 63.6% of the subjects tended to settle in the middle (not bored, not aroused 3 on scale). Figure 6 shows a comparison of the emotions overall throughout the sections of the test.

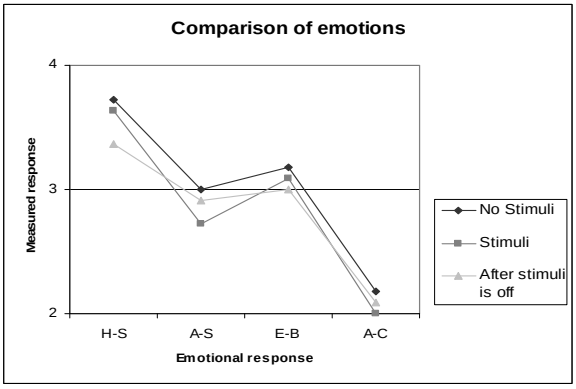

Figure 6. *Averaged comparison of emotions during the different sections of the test.*

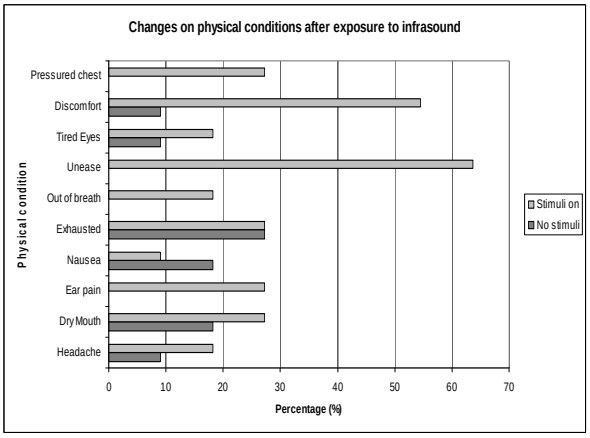

Figure 7. Physical responses comparison with and without stimuli present.

After asking them to describe in their own words how they felt when the stimulus was switched on, and if they felt any differences between the sections of the test (no stimulus, stimulus on, stimulus off), 36.4% of the population felt no physical sensation nor differences among the parts of the experiment. The remaining 63.6% described the effects on their body when the stimulus was on with words such as: "pain on the left side above the ear", "difficulty to focus", "hurting joints", "change in body pressure", "sensation of illness", and "pump in blood pressure" among others. When describing the difference between having the stimulus on and having it off; most of the subjects agreed on a feeling of relief and release of pressure.

The logic test held, showed no difference in timing response with the presence of infrasound. The average time answering the test with no stimuli was 2.8 minutes compared to the average time with the stimuli present being 2.7 minutes.

Pulse rate changes were more noticeable, where 45,4% of the subjects presented a decrease in it when the stimulus was on compared to when it was not present. The remaining 54,6% was divided into two equal groups where 27.3% had an increase in pulse rate while the rest showed no change at all.

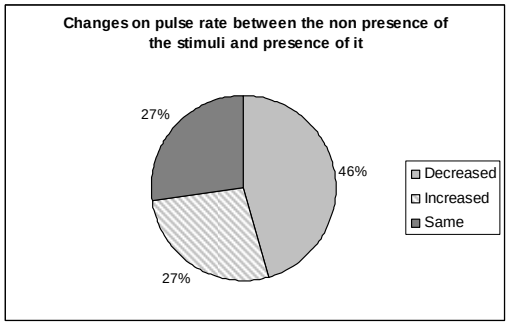

Figure 8. *Pulse rate changes between the non presence of stimuli and presence of it.*

5.2.3. Discussion

Even though the experiment was not as successful as thought, some conclusions can be derived from it. Similar to the London concert experiment, the emotional scale does not vary as

considered. The differences in people's emotions between test signals with and without infrasound stimuli do not follow any trend, and it can be said that it does not make a difference. Even though some trends can be seen, they are not strong enough to conclude that the presence of infrasound makes people feel in a special emotional way.

On the other hand, the effects on human physiology are somewhat more representative. Results show a resemblance to some of the effects that infrasound provokes in the human body described by researchers in section 4.1. Annoyance and discomfort are the most important ones; it is important to note that these physiological effects are the ones taken into account when trying to asses a standard for infrasound exposure and limitations for workers.

Although lower performance is claimed when workers are exposed to infrasound, in this specific case it did not happen. Logic tests, having the stimulus both on and off, gave the same results. One possible explanation for this outcome is the short time of exposure to infrasound (approx. 12 minutes when test was presented), as well as the low pressure level that the stimuli was played at (83 dB) in order to avoid distortion of the signal.

As described in 4.1, infrasound stimuli showed a tendency to decrease pulse rate among the subjects of the experiment. Even though the literature mentions a lower frequency range than the stimulus and higher intensity, the effects resembled the same trend.

6. CONCLUSIONS

Infrasound as a sound below the audible threshold can be heard by humans at high intensity levels or at least perceived. Different sources on earth produce these low frequencies such as natural phenomena, machines, animals, and weapons or man. Body organs resonate in this frequency range and therefore can be truly affected by these noises. Following this idea the military has been trying for several decades to come up with a non lethal infrasound weapon.

Other uses of infrasound are seen in contemporary music performances and art exhibitions, where the idea of feeling the piece instead of just hearing it is explored.

Infrasound is a source of physical changes in humans. Due to the resonant frequencies of several organs, changes in the performance of them can be experienced with the presence of this phenomenon. Caution is recommended for people dealing with these low frequencies, even though no international standard has been written..

In order to understand the concept and effects of infrasound explained in the literature, a small experiment was held among peers at the University of Sydney. Results showed a tendency of experiencing annoyance and discomfort in the majority of the subjects experiencing infrasound, and on a smaller scale pressure on the chest, ear pain and lack of breath. Emotional changes between sources with and without infrasound could not be determined.

Although it was interesting to see the way infrasound affects people (low levels were played and no harm was done in anyway) to get better results, a larger experiment would have to be held using higher sound pressure levels. Since it is really hard to determine results from subjective tests, most of all when physiological variables are present, it is necessary to revise the questionnaire and method in order to obtain more accurate results.

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[ii] Some of his work can be appreciated at: http://www.lustmord.com/discography.html.

[iii] For further information and complete results of this experiment, the following webpage is recommended: http://www.spacedog.biz/infrasonic/infrasonicResults.htm

Appendix A

PART I (No stimulus)

Age:_____
Gender: F___ M___
Background: _____

Physiological information:

1.	Do you suffer from dry eyes?	Y___	N___
2.	Do you suffer from blood pressure changes?	Y___	N___
3.	Do you suffer from headaches regularly?	Y___	N___
4.	Do you suffer from diabetes?	Y___	N___
5.	Do you suffer from any type of eating disorder?	Y___	N___
6.	Do you suffer from depression?	Y___	N___
7.	Are you claustrophobic?	Y___	N___
8.	Are you afraid of the dark?	Y___	N___
9.	Do you suffer from ear pain?	Y___	N___
10.	Do you suffer from vertigo?	Y___	N___

According to how you feel at this moment please answer the following questions:

1.	Do you have a headache?	Y___	N___
2.	Do you have a dry mouth?	Y___	N___
3.	Are your ears hurting?	Y___	N___
4.	Do you feel nauseous?	Y___	N___
5.	Do you feel exhausted?	Y___	N___
6.	Do you feel out of breath?	Y___	N___
7.	Do you feel unease?	Y___	N___
8.	Do you have tired eyes?	Y___	N___
9.	Do you feel discomfort?	Y___	N___
10.	Do you feel pressure in your chest?	Y___	N___

Emotion Scale

According to how you feel at this moment please answer the following questions:

Happy					Sad
	5	4	3	2	1
Aroused					Sleepy
	5	4	3	2	1
Excited					Bored
	5	4	3	2	1
Angry					Calm
	5	4	3	2	1

Time: _____

1. Please organize the number sequence below in order from the lowest to the highest

   12 45 3 25 7 34 31 9 22 5 2 15 13 20
   _____

Turn the page

2. Please organize the following letters in order Z-A

   K P T I O W N X C S G E L V H

   _____

Time: _____

Pulse: _____

PART II (after 10 minutes of stimulus exposure)

According to how you feel at this moment please answer the following questions:

1.	Do you feel nauseous?	Y___ N___
2.	Do you feel exhausted?	Y___ N___
3.	Do you feel your eyes are tired?	Y___ N___
4.	Do you feel out of breath?	Y___ N___
5.	Do you feel pressure in your chest?	Y___ N___
6.	Do you have a headache?	Y___ N___
7.	Do your ears hurt?	Y___ N___
8.	Do you feel unease?	Y___ N___
9.	Do you feel discomfort?	Y___ N___
10.	Do you feel your mouth dry?	Y___ N___

Emotion Scale
According to how you feel at this moment please circle:

Happy					Sad
	5	4	3	2	1
Aroused					Sleepy
	5	4	3	2	1
Excited					Bored
	5	4	3	2	1
Angry					Calm
	5	4	3	2	1

Time: _____

3. Please organize the number sequence below in order from the highest to lowest

   2 14 5 23 51 72 4 13 19 24 15 22 54 35

   _____

4. Please organize the following letters in order A-Z

   H E T M A Q C P K L V R I B J

   _____

Time: _____

Pulse: _____

Turn the page

PART III (No stimulus)

1. In a few concise words describe how you feel now that the stimulus signal is off:
   _____
   _____
   _____
   _____

2. Did you feel any difference between different sections of the test? Explain
   _____
   _____
   _____

3. Did you feel any unusual sensation while doing the 2nd part of the test? If so, please explain (when the stimulus was present)
   _____
   _____
   _____

Emotion Scale
According to how you feel at this moment please circle:

Happy					Sad
	5	4	3	2	1
Aroused					Sleepy
	5	4	3	2	1
Excited					Bored
	5	4	3	2	1
Angry					Calm
	5	4	3	2	1