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Is Noise Changing Our Climate?

During module CEM162, Gavin Irvine gave a lecture on building acoustics that focused on noise and the built environment (Irvine 2008). Jason Hawkes also talked about the role of noise in his lecture on the role of educational buildings in the development of school children (Hawkes 2011).

This paper looks at noise and its role in our lives and discovers that it has a big impact on our health and environment. But noise is not always a nuisance and this paper discusses some of its beneficial uses too. A field of research called Stochastic Resonance (SR) proposes that noise might also aid signal detection and response in various natural systems, and might help explain millennium-scale climate variability during the Ice Age, due to the weather system being much more excitable. This paper then poses the question as to whether SR has serious implications for the climate of our modern world, with its ever increasing noise levels and uncertain weather patterns, due to climate change.

Assumed is a working knowledge of some acoustic theory and the understanding of concepts such as sound pressure level (SPL) and the decibel (dB).

The Sound of Silence

The title of Simon and Garfunkel 's "The Sound of Silence" conveys the fact that even in the most quiet of environments, sound is ever present. This permanent background acoustic provides a reference, known as *'ambient noise*', that is relative to any given location. For instance, someone who lives near a busy road might be subject to an ambient noise level of 80dB (hopefully mitigated by double-glazing), whereas someone who lives in the countryside might experience a level as low as 35dB. For the latter, a car would disturb "the sound of silence", but that sound *is* silence for the former. Recently the author was sat in the garden of a friend on a lovely spring day when a train rattled past at the bottom of their garden. "Did the noise of that train bother you?", I asked. To which came the reply, "what train?"

What is Noise?

Noise can come in many forms. Environmental health officers would consider the sound of an errant burglar alarm as noise. Communications Engineers regard noise as the undesirable element of a signal. Computer Scientists think of it as meaningless data and Audio Engineers as a residual signal that results in an unwelcome "hiss". To a Biologist it could be the variable element of two identical experiments or the background fluctuations that distort measurement (McDonnell & Abbott 2009).

Noise is Bad

Generally then, noise has a nuisance association and is something that is unwanted. Indeed, the word noise is derived from the Latin for nausea; something

that we have a strong aversion to, or disgusts us. Hence, noise has negative connotations.

Noise and Regulation

In terms of regulation, noise is deemed as any audio over a certain sound pressure level for a given duration. Thus, in regulatory terms, noise is defined in terms of time and loudness and often helps to define hazardous working environments, where noise might be considered a nuisance. In 2005, the UK's Noise at Work Act stipulated that an employee must not be subject to a daily or weekly exposure of an average SPL of 80 dB, or peak 135 dB (Health and Safety Executive 2005). Starbuck's should take note; on the afternoon of 31st March, 2011, the author sat for two hours in their cafe on North Road, Brighton and registered an average sound pressure level of 85dB. That particular branch of Starbuck's might well be breaking UK law when the cafe is extremely busy on bright summer weekend days.

But One Person's Noise is Another's Music

But loud isn't always noisy, yet quiet might be! Just as the sound of silence depends on context, so does noise; place yourself in the study area of a library and imagine your reaction to a seemingly quiet conversation across the table. Even though that conversation might only reach a very safe and inoffensive 40dB, it is certainly noise to you (the studious type trying to concentrate). Then imagine that later that evening, after a good days work (once you told those noisy people in the library to be quiet), you feel like relaxing and watching a band at your favourite club. This time the sound will probably reach something in excess of 120 dB, well above the recommended average levels of the UK's Noise at Work act and certainly way in excess of the conversation in the library. But this time the 'noise' will be very welcome!

Noise and Well-being

The reason regulation such as the UK's Noise at Work Act exists is because long-term exposure to loud sound affects one's well-being. The World Health Organisation list hearing loss, stress, mental-health issues and performance impairments amongst the possible long term physiological effects on one's health, if over exposed to noise (Berglund et al. 2001). The human auditory system evolved to aid our survival in natural environments and so it has simply not adapted quickly enough to cope with the ever increasing sound intensities of modern urban and industrial noise. Furthermore, the inner ear has a direct connection to defensive "fight or flight" neural mechanisms, which cannot be switched off during sleep (Westman & Walters 1981). Hence, noisy environments are not restful ones.

Noise and Animal Welfare

There is increasing concern that noise might have an effect on animal welfare too. For example, man-made noise in our oceans has been proposed as the cause for phenomena such as whale strandings (Azzellino et al. 2011). Indeed, the European Union's Marine Strategy, adopted in June 2008, defines underwater noise as a form of pollution that:

"*...is likely to result in deleterious effects such as harm to living resources and marine ecosystems"* (Rice 2010).

Even if proof of noise induced cetacean beachings is not yet definitive, changes in animal behaviour due to noise have been noted, with Schevill indicating that the noise from boats causes unusual whale responses, such as shortened surfacing and interrupted feeding (Schevill 1968). And a German study discovered that in order to be heard at noisy locations, Great Tits sing at a higher pitch (Slabbekoorn & Peet 2003).

Noise Isn't Always Bad

Yet in spite of all the bad press, it turns out that noise has some practical applications too; your iPod would not sound quite like it does without it!

Distortion and Digital Recording

Whenever any sound is recorded into the digital domain, the signal is 'downsampled'; reduced from a limitless, continuous analog signal to a finite, discrete, digital representation. This downsampling creates distortions that our ears would find unpleasant. So a process known as *dithering* takes place, whereby noise is added to spread these distortions across the frequency spectrum, creating a broadband noise that our brain is very good at filtering out. A further benefit is that the added noise takes parts of the original signal that would otherwise be inaudible and pushes them over a transition point. Our ears and brain, skilled at separating such a signal from the background noise, does the rest and makes those parts audible (EarLevel Engineering 1996).

Noise Masking

The web site simplynoise.com features a white noise generator; digitally generated noise that can create a loud and continuous broadband background 'hiss'. Although one might imagine it's raison d'être is to create an annoying din, in fact the site has many fans:

"*Hello! I love your website as I live in noisy NYC. It really helps me get a deep sleep without disruption.*" Jonathan, (simplynoise 2010).

"*I love you guys! My place is always noisy and the only way to get a decent nap in is with your website. Keep on making noise!*" -Kevin F., (simplynoise 2010).

Clearly, for the adherents to the site, the broadband noise it generates masks much more annoying noise. But in fact, such generators could have serious health applications aside from alleviating the stress caused by urban noise. Sufferers of tinnitus have a persistent ringing within the human ear, even when there's no corresponding external sound. Often this is caused by damage from over-exposure to loud noise. Research is ongoing as to whether digitally generated white noise can mitigate the effects of tinnitus (Jastreboff 2007), with websites such as noiserelief.com seeming to suggest that indeed it can. They believe this is because the brain is very good at filtering out sound that it thinks carry no information. The effect then is proposed to be similar to the author's friend not hearing the train that rattled past the bottom of their garden; because it is heard so often, habitual use of white noise eventually leads the brain to discard its sound, along with the tinnitus it masks (noiserelief.com 2008).

Stochastic Resonance and Climate Change

Stochastic Resonance (SR) is a burgeoning research field that proposes that signal detection and transmission can benefit from a certain optimum level of random noise. It requires that three basic ingredients are in place: 1) some form of threshold over which energy activation occurs. 2) a weak signal. 3) an inherent source of noise. The basic idea is that noise can increase the weak signal's detectability once it is pushed over a threshold, thereby amplifying the signal's influence on nonlinear, dynamic surroundings. SR is in vogue because many natural systems are dynamic, nonlinear and noisy and the idea that they might have evolved in order to perform best under ambient noise levels is provocative (Gammaitoni et al. 2009). Topics for research into SR include sensory systems of crayfish (Douglass et al. 1993), the human central nervous system (Mayor & Gerstner 2005) and quantum computing (Yamamoto 1992).

However, the original idea of SR came as a theory to explain 100,000 year cycle of the Ice Ages (C. Nicolis & G. Nicolis 1981) and (Benzi et al. 1983). Although this theory was brilliant, it was not supported by subsequent evidence. But a 2002 study revitalised research into SR and weather systems, demonstrating that it might help explain why the Ice Age climate was so much less stable compared to that of the past 10,000 years and that it could have been an important mechanism for millennial-scale climate variability during glacial times (Ganopolski & Rahmstorf 2002).

Could Stochastic Resonance have massive implications for our present environment? Ganopolski & Rahmstorf's computer models suggest that an influx of noise would have produced resonant amplifications of glacial warming events similar to those found in the observed climate records, because during the Ice Age the oceans experienced a much wider variation of conditions than they do today (Ganopolski & Rahmstorf 2002). But as we move toward a more chaotic weather system, could our ever noisier modern world amplify the effects of climate change? Might we be reaching a threshold where the noise we generate tips our weather system over the edge and moves us into a new climate age?

Conclusion

In a world promising a future of ever more noise, health studies and research fields such as Stochastic Resonance have an important role to play in helping us to understand the role noise has in our lives. Because until we comprehend the impact of noise, how can we harness it, or help mitigate its detrimental effects on society and on the environment that supports us?

Limitations and Further Research

This paper touches only briefly on the role of noise in our environment. Any of the topics discussed would be great areas for further research.

For instance, what are the effects of noise on our central nervous system? Although noise has many detrimental health implications, Stochastic Resonance suggests that it might play an important role in helping us to process signals too. Regarding policy, how is regulation used around the world and how do different societies deal with 'noise'? Can the positive masking effects of noise be used more widely to help mitigate the problems of sound in urban environments? For instance, might noise be used to help those suffering from sleep deprivation in busy city centres? Might implants that generate white noise be used to help sufferers of tinnitus?

It would also be extremely interesting to research the effect of noise on the environment. Could Stochastic Resonance really have a role to play in climate change? And even if the effects of noise are not quite so dramatic as to amplify global warming, with studies suggesting that noise has an effect on animal welfare, might the increase of noise help explain the UK's declining bird populations (Royal Society for the Protection of Birds 2008)? Perhaps the Song Thrush has tailed off so disastrously because it is struggling to be heard over the din of the modern world? With the ambient noise level increasing in our oceans (McDonald et al. 2006), could this help explain decreasing blue whale numbers too? Maybe they are struggling to be heard over the hum of shipping?

Noise is a fascinating subject because it permeates all of our lives, whether we are aware of it, or not.

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