Acoustics and Vibration in the Time of the Pandemic

Each June this editorial space is dedicated to reporting the updates of our annual congress, the International Congress on Sound and Vibration, ICSV, that was to be held this year in Prague. However, the current circumstances have forced us to reluctantly postpone the Congress to July 2021. The spread of the COVID-19 worldwide has caused the postponement and cancellation of most of the scientific congresses scheduled for 2020. This has hurt many planned events and activities making the International Year of Sound less visible to the public.

The new virus was first identified in Wuhan, China, in December 2019 (The Lancet 2020; 395:497–506) and rapidly spread worldwide. The International Committee on Taxonomy of Viruses (ICTV) named the new virus as SARS-CoV-2 and the disease as COVID-19. The pandemic, declared by the World Health Organization in March 2020, has completely changed our lives and has compelled universities and research centers to confront long-standing challenges. The coronavirus crisis has forced us to adapt to working remotely from home, including teaching our students using a number of online platforms. One of the dilemmas is graduate students cannot access our laboratories which is causing significant delays to those research projects involving experimental work.

It is difficult to envisage all the effects that this pandemic will have on our societies, although it is plausible to expect severe effects on the global economy. This is mainly because of a decrease in international trade as well as quarantines and extended lockdowns restrictions imposed by most countries to contain the spread of the virus. A great deal of institutions worldwide are currently facing major financial problems. In a post-pandemic world, universities and research funding agencies will reduce their budgets and will probably focus their efforts on supporting coronavirus-related work, which may thrive in the biological sciences. However, acoustics and vibration related research has been active since the COVID-19 outbreak.

One of the most noticed effects caused by the mobility restrictions has been a quieter planet. Environmental noise in modern cities is mainly caused by traffic. This noise has been associated with several diseases, including stress, sleep disorders, and high blood pressure, among others. In an editorial, Aletta and Osborn (UCL Open: Environment 2020; 1:5) have reported that since the enforcement of the lockdown in France, an average reduction in the A-weighted day-evening-night sound level (L_{den}) of 7.6 dB was observed on the Paris road network. Similar observations have been made in Barcelona where the noise levels decreased by 9 dB one week after the implemented lockdown. A further reduction of 2 dB was observed there during the following week. This environmental noise reduction has been more significant in the vicinity of large airports because of the provisional cancellation of many domestic and international flights. Aletta and Osborn also indicated that aircraft noise emissions for the Paris

Charles De Gaulle airport dropped by an impressive L_{den} of 21.5 dB.

This reduction of noise has changed the city soundscapes and has produced a very pleasant effect on people. After the lockdowns, many residents of large cities have noticed how they can now hear nature sounds, mostly birds, that normally are muffled by the man-made background noise. This may also be one of the explanations for the recent unusual spotting of wildlife in major cities.

Traffic, trains, and heavy machinery in construction sites are also strong sources of vibration. Vibration waves travel through the ground generating background vibrations that can be detected by seismometers. Seismologists and geoscientists have benefited from the reduction in anthropogenic noise and seismic activity. Now they have been able to detect smaller earthquakes, improve the detection of earthquake aftershock locations, and increase knowledge about the Earth's crust which seemed impossible before the coronavirus outbreak. This effect has been recently reported by several researchers across the world (Nature 2020; 580:176-177).

However, the pandemic has also affected the practicality and reliability of baseline sound level surveying which is an essential stage of a noise impact assessment of a planned project. This fact has been noted in April 2020 by the Association of Noise Consultants and the Institute of Acoustics in the UK. Both institutions have issued guidelines to acoustics professionals to provide high-quality acoustic reporting in a timely manner to authorities, the public, and decision-makers.

Interruption of operations of cruise ships and the slowdown in global trade activity due to the pandemic have also led to quieter oceans. Marine shipping is the main contributor to ocean noise levels in the 10 – 1000 Hz frequency range. Ocean noise is monitored nearly in real-time through many deployed multi-sensor ocean observatories around the world. This was the subject of a paper published a few weeks ago by Thompson and Barclay (J. Acoust. Soc. Am. 2020; 147:3390-3396). They reported an average reduction of 1.5 dB in year-over-year mean weekly noise power spectral density at 100 Hz during the first quarter of 2020. These data come from hydrophone measurements at one of the observatories on the Canadian Pacific coast. These quieter conditions, that will remain perhaps for some months, should be positive for marine life. Research has shown that the noise from maritime traffic has an enormous impact on marine organisms mainly affecting their reproductive success (Nature 2019; 568:158-161).

Acoustic research has also been conducted on ways to diagnose and identify the new virus. An acoustic digital diagnostic system developed by Sanolla in Israel has been designed for early diagnosis and management of chronic respiratory disease. The system is based on the detection of infrasound signals, sounds with frequencies below 20 Hz, from a patient's lung. These signals are subsequently classified and analyzed

employing artificial intelligence algorithms and deep learning techniques. The system has lately been expanded for early diagnosis of the COVID-19 disease.

A study published in March 2020 by Italian researchers (J. Ultrasound Med. 2020; 9999:1–7) has outlined acquisition protocols for performing lung ultrasonography on patients exhibiting the COVID-19 infection. Although radiography and computed tomography are also used for diagnosis and treatment of respiratory diseases, lung ultrasonic techniques have the advantage of being used at the patient's bedside thus diminishing the risk to health workers of virus exposure.

One of the most common features that doctors have noticed in patients with the COVID-19 infection is the way they catch their breath when speaking, as well as a dry cough and their respiratory patterns. Based on these observations, a team of multidisciplinary scientists at the University of Cambridge has presented a mobile application, the COVID-19 Sounds App, that collects data to diagnose COVID-19 using artificial intelligence. The application will assist scientists in developing machine learning algorithms that could automatically determine if a person has COVID-19, based on how they speak, cough, and breathe. Currently, there is a search for volunteers to test the app which can be accessed at their website (<https://www.covid-19-sounds.org>). It can be expected that the outcomes of this research will be particularly valuable to developing countries that have limited healthcare facilities.

Markus Buehler, a Professor of Engineering at the Massachusetts Institute of Technology has used a novel nanomechanical sonification method to create an audio signal that features an overlay of the vibrational signatures of protein structures (ACS Nano 2019; 13:7471–7482). The virus causing COVID-19 has a spike protein, a crown-like protein on the outer surface of the virus, which gives a coronavirus its name. Through sonification, it is possible to compare the biochemical processes of COVID-19's spike protein with previous respiratory viruses, such as those causing SARS or MERS. From the audio signal, the vibrational structure of the spike protein that infects the host is analyzed as a piece of counterpoint music. Ultimately, researchers could be able to search for a new protein that matches the melody and rhythm of an antibody capable of binding to the spike protein, inhibiting its capability to infect.

Some recent research efforts have been focused on the development of innovative ways to ensure that a virus cannot infect a host. One of these lines of research attempts to use a vibration resonance to inactivate a virus. All objects have natural frequencies of vibration and each frequency is associated with a vibration mode. Natural frequencies are often dependent upon the dimensions and the material properties of the object. When the object is excited at one of these natural frequencies, then resonance occurs, and the object is forced to vibrate at a high amplitude.

Viruses are biological objects with nanometric dimensions, typically ranging from 10–100 nm, whose elastic properties are difficult to know due to the specificities of viruses. These properties are vital to determine the vibration mode frequencies of a virus. Vibration modes of viruses are also damped when they are embedded in a liquid.

The protein shell of a virus particle that surrounds its nucleic acid is called the capsid. This capsid protects the core and the genetic material inside the virus. SARS-CoV-2 also has an outer lipid membrane. It is known that viruses with a lipid envelope are generally the most fragile. Considering

this fact and the fact that viruses can absorb ultrasonic energy, researchers have proposed to resonantly excite viruses to selectively destroy them. The method physically fractures the virus structure causing its inactivation. It seems that the idea of using resonant absorption of ultrasound energy as a method of HIV destruction was first hypothesized in 2000 by a team of biophysicists from Slovakia and the USA (Medical Hypotheses 2000; 55:450–451).

A coronavirus has a nearly spherical structure. Stephanidis and his colleagues at the Universities of Lyon and California have indicated that, in the case of a nanosphere, the frequency of the spherical (breathing) mode is inversely proportional to the particle diameter and proportional to the speed of the longitudinal wave in the nanosphere (Biophysical J. 2007; 93:1354–1359). In the case of the quadrupolar mode, its frequency is proportional to the speed of the transverse wave. In February 2020, a group of researchers in South Korea were able to successfully isolate and observe through electron microscopy the new SARS-CoV-2 morphology (Osong Public Health Res. Perspect. 2020; 11:3–7). They reported that the size of the virus particles ranged from 70–90 nm, so their vibration modes are in the GHz ultrasonic region. Although it is difficult to measure the vibration mode frequencies of viral structures, a method has been recently reported by a research team from China and Canada (Appl. Sci. 2020; 10:394).

Researchers in the Department of Physics at Arizona State University have shown that ultra-short pulses of laser light can induce destructive vibrations in virus capsids (Virol. J. 2014; 11:20). The pulse is applied by a short time, of the order of one femtosecond, that is about a quarter of a period of vibration to induce a mechanical shake. However, the technique is far from being used to inactivate viruses in infected people. Another approach by researchers considers the structure-resonant energy transfer from microwaves to confined acoustic vibrations in viruses. This induces maximum stress on the lipid membrane of the virus envelope resulting in fracture and inactivation at its dipolar resonance frequency (Sci Rep. 2015; 5:18030).

At the moment of writing this note, these methods for inactivating viruses have not yet been applied to SARS-CoV-2. However, several researchers have reported successful attempts to inactivate other viruses in the past, such as the influenza A virus, which is contained in the genomic sequence of the virus that causes the COVID-19 disease. This can be a viable alternative to current human-hazardous methods to kill airborne viruses such as chemical, UV irradiation, and microwave thermal heating. Research on these areas continue.

We remain hopeful that science and technology will stop the pandemic. But, until the development of either a vaccine or a reliable treatment of the COVID-19, we all have a responsibility to protect our health and the health of others by implementing physical distancing, wearing face masks, and practicing frequent handwashing.

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