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Helping deaf people feel the music

HOW THE ACOUSTICS RESEARCH UNIT AT THE UNIVERSITY OF LIVERPOOL BRINGS THE JOY OF MUSIC TO DEAF PEOPLE USING THE POWER OF VIBRATION.

HBM

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MUSIC IS EVERYWHERE – FROM DEDICATED MUSIC VENUES TO OUR HOMES, FITNESS CENTRES, CAFES, SHOPS, CARS AND EVEN ELEVATORS – MUSIC IS ALL AROUND US, PROVIDING PLEASURE AND SOLACE.

A world without music is, for most of us, unthinkable. But for the eleven million people in the UK alone who have some form of hearing loss (approximately one in six people), and the approximately 900,000 people with a severe or profound hearing loss, a world with music has not always been accessible – until now. A University of Liverpool project, funded by the Arts and Humanities Research Council, is using vibrotactile technology to support deaf people in music education, performance, appreciation and production.

Hearing through the skin

In 1926, Robert H. Gault, Professor of Psychology at Northwestern University, wrote a paper entitled 'Touch as a Substitute for Hearing in the Interpretation and Control of Speech'. In it he gave an account of experiments he'd conducted "where the vibration of a speaker's vocal apparatus are (sic) transmitted through a suitable electrical device to the skin of a 'listener'. He feels the very vibrations that occasion normal people to hear." This was the first time that the potential for vibration to allow 'hearing through the skin' was first considered. Today, as back then, communication tends to receive the most attention in hearing loss research, but access to music, and participation in music-making is also important.

Modern research into the tactile perception of music by D/Deaf* musicians has largely been inspired by Scottish virtuoso multi percussionist Dame Evelyn Glennie, classified as 'profoundly deaf with residual hearing at high amplification' since the age of 12, having started to lose her hearing from the age of 8. She regularly plays barefoot during both live performances and studio recordings to better feel the music. She says, "People think that music means nothing to the deaf; but it is important to them whether they are interested in it or not. The satisfaction of feeling vibrations, and being able to communicate through music, gives deaf children the greatest pleasure."

Converting musical sounds into vibration

Building on previous research, The Musical Vibrations project (www.musicalvibrations.com), from the Acoustics Research Unit at the University of Liverpool aims to bring music to d/Deaf** people in schools, live music venues and music production studios, using the power of vibration. The project, run by Professor Carl Hopkins, Natalie Barker (music teacher) and Dr Gary Seiffert aims to demonstrate the potential of using vibrotactile feedback, that is, sound presented as vibration that is felt via the skin.

The initial research considered the feasibility of group rehearsal, performance and improvisation for musicians with hearing impairments. The basic concept being that any musical performance can effectively be turned into a computer-controlled amplified performance where the sound from each instrument is taken to a mixing desk and sent back as a vibration signal to be presented to the body of the musician. This established that the concept was feasible for the perception of notes from C1 up to G5 with safe levels of vibration presented to the glabrous (non-hairy) skin of the hands and/or feet.

** 'Deaf' refers to people who are born deaf or experience hearing loss before spoken language is acquired and regard their deafness as part of their identity and culture rather than as a disability. They form the Deaf Community and are predominantly British Sign Language (BSL) users. (Source: www.deafax.org)*

*** 'deaf' refers to people who have become deafened or hard of hearing in later life, after they have acquired a spoken language and so identify themselves with the hearing community. d/Deaf people are more likely to use hearing aids and develop lipreading skills. (Source: www.deafax.org)*

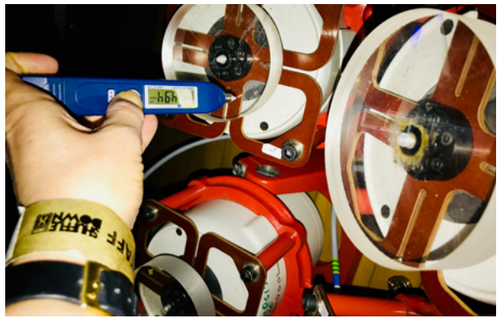
Putting the concept into practice

The equipment set-up was originally designed for the research to establish vibrotactile thresholds, potential dynamic range and the highest frequency that could safely be perceived using the finger, forefoot and heel (read more about it). To deliver vibration to the human body, the Acoustics Research Unit used permanent magnet LDS shakers with sturdy trunnions and armature. These were chosen to ensure a flat frequency response over a range of musical notes from C1 (32.7 Hz) to C6 (1046.5 Hz) with negligible effect from mass loading due to the human body when hands or feet were placed on the contactors that were fixed to the shaker. Note that voice coils and other lightweight exciters are not ideal for precise, controlled presentation of vibrotactile stimuli to the skin, because of uneven frequency responses and reduced output due to damping when in contact with the skin.

The LDS V201 was used to apply vibration to the finger and the LDS V406 to apply vibration to the forefoot and heel. The contactors to the skin were smooth metal or Perspex discs that were screwed into the shakers. These had diameters of 2 cm, 12 cm and 10 cm for the fingertip, forefoot and heel respectively. Relatively large contactor surfaces were chosen to ensure they would be practical for musicians and singers during music performance and to facilitate spatial summation by the Pacinian mechanoreceptors in our glabrous skin. Participants were instructed to relax their arm/hand or leg/foot and not to press down upon the contactors. However, the LDS external suspension unit was needed on the LDS V406 to minimise the effect of mass loading produced by the leg of the body when the person was seated. The trunnion mount of the LDS 406 allowed each shaker to be angled so that the foot could rest comfortably on both contactors. The shakers were driven using Brüel & Kjær power amplifiers connected to a high-quality sound card to give low-level harmonic distortion such that harmonic peaks were at least 40 dB below the fundamental frequency used as the test note. Acceleration and force measurements were made using Brüel & Kjær accelerometers, force transducers, NEXUS™ conditioning amplifiers and the PULSE™ multichannel analyzer.

The research identified that notes from C1 (32.7 Hz) to G5 (784 Hz) would be perceivable with vibrotactile presentation at levels that carry a negligible health risk due to exposure to vibration. This frequency range is significantly limited compared to human hearing but the fundamental frequencies of the human voice, and the notes played by many instruments, lie within it. In terms of pitch perception, it was shown to be possible to identify intervals of three to twelve semitones with greater than 70% accuracy after relatively little training.

The next step was to create an equipment set-up that could be used in music lessons at the Royal School for the Deaf Derby (RSDD). In the laboratory experiments it was necessary to structurally isolate the shakers and to encase them in a sound enclosure or use masking noise to avoid radiated sound from the shaker casing. However, this was not necessary in the classroom because most of the children were profoundly deaf and any residual sound was not problematic. For the relatively small class size, the system consisted of two LDS V201 and four LDS V406 shakers. This typically allowed two children to sing and four children to play keyboards, bass guitar or other instruments. Rack mounted stereo amplifiers and a standard analogue mixing desk were used to take signals from the musical instruments and microphones. Importantly, each output of each channel had an electronic signal limiter to ensure safe levels of vibration. The vibration output could also be periodically checked by the teacher using measurements with a simple hand-held vibration indicator.



Left: The contactors to the skin were Perspex discs screwed into the shakers with diameters of 2 cm, 12 cm and 10 cm for the fingertip, forefoot and heel respectively; Right: Checking the vibration output using a hand-held vibration indicator.

Feeling the difference

A video, Using vibrotactile technology to support d/Deaf people in music education at Royal School for the Deaf Derby, funded by the UK Acoustics Network, documents the experiences of staff, pupils and providers who used and observed vibrotactile equipment in music lessons. Matthew Taylor, music teacher at the school commented that the equipment, "has certainly given our children greater access to sound…particularly in the area of pitch, they are now beginning to make the connection between the vibration and the pitch of the note, where before, a lot of our students would get confused." He continued, "It is changing the way I teach" and on entering the room the children now immediately take their shoes and socks off before the lesson has even started. The value of using vibrotactile feedback was confirmed by teaching assistants and pupils, with a Year 9 pupil explaining "… they help me to recognise low, middle and high pitch."

> IT IS CHANGING THE WAY I TEACH

Matthew Taylor, music teacher, Royal School for the Deaf Derby

Additional educational value was evident in behavioural changes with increased teamwork and social interaction between pupils. It also transpired that the vibrotactile approach helps protect the teacher's hearing and improves the learning environment. The music teacher commented that "…in the past…volume levels have been very high and that can affect hearing staff because we have to wear earplugs…with the inclusion of the vibrotactile equipment, I now have control…and it also creates a much calmer atmosphere".

After trying the Musical Vibrations system out in their music lesson, these keen pupils at the Royal School for the Deaf Derby asked to return to have another go at lunchtime.

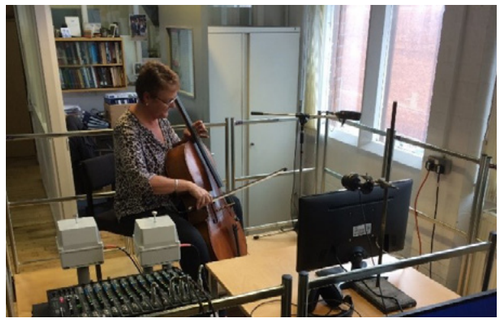
> HBK'S LDS ELECTRODYNAMIC SHAKERS WERE ORIGINALLY DESIGNED FOR COMPLEX VIBRATION TESTING OF DEVICES RANGING FROM A SEMICONDUCTOR COMPONENT TO A COMPLETE SATELLITE SYSTEM.
>
> HOWEVER, WE ARE DELIGHTED TO SEE THEM BEING USED TO CREATE INCLUSIVE OPPORTUNITIES FOR DEAF PEOPLE TO ACCESS MUSIC, TO PARTICIPATE IN MAKING MUSIC AND TO ENABLE MUSIC EDUCATION IN SCHOOLS FOR DEAF CHILDREN.

Brian Zielinski-Smith, VTS Product Manager

Other applications

Musical performance

The versatile system can be used with any electronic or acoustic instrument that can be mic'd up or used with a pickup converting the sound into vibration. A musician can 'listen' to four different signals by using the heels and toes of both feet, whilst leaving the hands free.



Cellist using a pickup to convert the sound of a cello into vibration which can be felt through the shakers

Music appreciation

Deafness does not impede the appreciation of live and recorded music. One way for d/Deaf people to explore the vibrations generated by sound systems is by touching a loudspeaker or wall in a music venue to feel the music, or as Aharona Ament writes in her book Beyond Vibrations: The Deaf Experience in Music, "One can try touching the ground and placing a back against walls at shows trying to see if they can tell the difference in rhythm and the type of instrument being played by the feelings that hum along the body when the music infiltrates the molecules in the walls and in ourselves as well."

With its six different vibrotactile elements, the Musical Vibrations system can transmit up to six different musical signals (for example from different instruments) through the palms, heels and forefeet of the listener. These signals can be felt on separate areas of the body.

Feeling the music at a live concert using four foot shakers

Another example of the system's potential in music appreciation is best demonstrated in this video created by the University of Liverpool Acoustics Research Unit. Watch the wonderful reactions of WJ, who became profoundly deaf about 8 years ago, when she 'feels' one of her favourite songs of the past – Phil Collins' In the Air Tonight.

Music production

Vibrotactile technology facilitates music production by musicians and producers who are deaf by replacing auditory cues. Separate audio outputs from a digital audio workstation (DAW) can be sent (via an audio interface) to the vibrotactile shakers, enabling 'vibrotactile monitoring.'

D/Deaf producer, writer and sign-song rapper SignKid has tried other vibrotactile products such as the Subpac and Wowee speaker but didn't get on with them. He has also experimented with a vibrating vest but found it quite uncomfortable and disconcerting to use. Acoustics Research Unit at the University of Liverpool invited SignKid to try out the Musical Vibrations vibrotactile equipment out to see if it might help him with music production and live performance.See how he got on

SignKid using four vibrotactile foot shakers to jam in time with a multitrack recording

Special thanks go to:

Professor Carl Hopkins (Head of Acoustics Research Unit), Dr Gary Seiffert (Senior Research Fellow) and Natalie Barker from the Acoustics Research Unit at The University of Liverpool.

Sources

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