New Technology to Help the Hearing Impaired Enjoy Music

Research develops prototype which enhances the ability of people with hearing disabilities to enjoy music

A multi-disciplinary research team based in the NUS Faculty of Engineering has developed a prototype Haptic Chair designed to enhance the ability of people with hearing disabilities to enjoy music. The word "haptic" is derived from a Greek word which means "touch". As its name suggests, the Haptic Chair provides tactile sensations that correspond to a piece of music being played. To add an extra dimension, a visual display presents interpretations of the music in various ways.

The research team has conducted a series of formal user studies, the latest with 43 deaf participants. The number of subjects is important because the team wants the results to represent a range of hearing disabilities. The findings suggested that the prototype system does enhance the musical experience of a deaf person. Users preferred either the Haptic Chair alone, or with an additional visual display that reflects the mood of the music being played.

The project is led by Dr Elizabeth Taylor who heads the Marine Mammal Research Laboratory at the Tropical Marine Science Institute, in collaboration with Assoc Prof Ong Sim Heng, Head of the Bioengineering Group in the Department of Electrical and Computer Engineering, and Assoc Prof Lonce Wyse, Communications and New Media Programme, Faculty of Arts and Social Sciences.

The Haptic Chair team (from left): Mr Suranga Nanayakkara, Dr Elizabeth Taylor, Assoc Prof Lonce Wyse and Assoc Prof Ong Sim Heng.

Dr Taylor has a long-standing interest in multi-sensory perception and how dolphins employ "echolocation" - or "BioSONAR' to investigate their environment in conditions where vision is limited. Dr Taylor explained that by applying the same logic, perhaps humans can also benefit from a conceptually similar 'cross-modal' sensory experience.

This idea sparked off Mr Suranga Nanayakkara's exploration of the world of the deaf. It was his research topic for his PhD after he graduated from the Faculty in 2005 with a first-class Honours degree in Electrical Engineering. He started by experimenting with how visual displays that reflect music in real time could help the deaf to enjoy music. Subsequently, he explored ways to augment this experience by increasing the intensity of vibrations naturally produced by sound - hence the Haptic Chair.

"Sound transmitted through the air and other physical media such as floors, walls, chairs, water, act on the entire human body, not just the ears. That's one of the reasons that space which is a virtual vacuum is reported to be totally silent -- there's nothing there that can conduct sound waves. The denser the medium, the better sound will be conducted," Dr Taylor explains.

Though the sound frequency range for tactile perception (often reported as 10-1000Hz) is considerably less than hearing perception, the team believes that the role played by higher frequencies in tactile perception is still an open question and continues to explore the upper limits of sounds which humans can perceive by touch through receptors in the skin -- which are actually bone conduction of sound.

It is possible that the role of higher frequencies in more realistic audio signals, for instance, in creating sharp transients, could still be important. Another exciting possibility is that in addition to tactile sensory input, bone conduction of sound directly to the ear or by-passing a non-functional ear and going straight to a higher processing system in the CNS (central nervous system) may provide an additional route for enhanced sensory input.

Bone conduction of sound is likely to be very significant for people with certain hearing impairments as a far greater range of frequencies is transmitted via bone conduction of sound compared to purely tactile stimulation. The research team is now exploring AM (amplitude modulated) ultrasonic carrier waves which can enable the profoundly deaf -- people deaf from birth who have never heard a sound in their entire lives -- to receive sound signals.

This work indicates that people can "feel" sound - including those who have no hearing impairment. Coupled with enhancement provided by visual images such as human expressions (that correspond to the music) and abstract visuals that provide information about the music, a deaf person's enjoyment of music can be increased tremendously. These techniques are also great fun for those with normal hearing!

"The prototype Haptic Chair was very well received by those involved in the graded series of user studies. Based on these results, we are now sure it will significantly change the way the deaf community experiences music," said Suranga who recently presented his study at the CHI (Human Factors in Computing Systems) Conference 2009 in Boston, USA. Organised by the Association for Computing Machinery, the conference showcased technologies, designs and ideas for a new digitally-enhanced world.

How the Haptic Chair Works

"The research team's Haptic Chair has four contact speakers linked to a music source, enabling it to vibrate in intensity according to the sound signals it receives," Assoc Prof Ong explained. A deaf person sitting in the chair is able to experience the music and their experience is qualitatively similar to a normal person. No particular frequency bands of the sound signal are amplified, so it is left to the user to work with the entire information stream.

The closest commercially available comparisons to the proposed Haptic Chair include the "Vibrating Bodily Sensation Device" from Kunyoong IBC Co, the "X-chair" by Ogawa World Berhad, the "Multisensory Sound Lab" (MSL) from Oval Window Audio, and Snoezelen® vibromusic products from FlagHouse, Inc.

Also a team from Ryerson University, Canada is working on a similar chair called "EmotiChair". This chair transforms an audio signal into discrete vibro-tactile output channels using a Model Human Cochlea (MHC), and these output channels are presented in a logical progression along the back of the body.

These devices are designed to process sound, including music inputs according to pre-defined transformations before producing haptic output.

"Our current system is different from most of the above because we do not electronically pre-process the natural vibrations produced by music. Because people sense musically derived vibrations throughout the body when experiencing music, any additional or deliberately altered 'information' delivered through this channel might disrupt the musical experience, and this confounding effect is potentially more significant for the deaf," Dr Taylor explains.

"The mastoid bone behind the ear, for example, can pick up such vibrations from ultrasonic waves which the brain can translate and interpret," she added.

Suranga conducted a background survey at the National Council for the Deaf, Sri Lanka, the Singapore Association for the Deaf, and the National Centre on Deafness, California State University, USA to find out what hearing-impaired people might find most useful in helping them enjoy musical performances. Based on the results of the background surveys and the informal interviews with hearing impaired people, the team developed a prototype system designed to enhance the musical experience of the deaf. He and his Haptic Chair have created a great amount of excitement and cheer at Dr Reijntje's School for the Deaf in Sri Lanka.

"The students were evidently swaying and moving to the rhythms of the music they were sensing," he said. As the Haptic Chair is designed for use by one person at any one time, the research team installed a "Sound Floor" in Dr Reijntje's School for the Deaf. This is a solid wood floor that vibrates according to the sound input provided by five contact speakers. Students using this "Sound Floor" for dance sessions have reported that they 'no longer need to watch the teacher all the time for cues to the music: they can feel these through their feet, and a group of students and teachers can work together using this platform.

A hearing impaired pianist at the NUS Yong Siew Toh Conservatory of Music has also tried the Haptic Chair and was pleased by how the sensation corresponded to the music he listened to or played. The talented17-year-old student who is 85 per cent deaf and who presently relies on a conventional hearing aid to provide musical feedback, told the research team that he would need input such as the Haptic Chair provides, if he eventually loses his hearing completely.

Ms Lily Goh, who is deaf and teaches percussion music and other performing styles to the Canossian School, Singapore School for the Deaf and Mountbatten Vocational School, has also tested the Haptic Chair. She was equally amazed that she could sense music through tactile and visual enhancements.

The research team continues to fine-tune their system so that it will offer maximum enjoyment of music for the deaf. "Sometimes solutions could be quite simple -- like just adding karaoke-like lyrics to the visual display", said Assoc Prof Wyse.

Moving forward, the team is adapting the Haptic Chair so that it might also help teach the deaf to speak. They have filed a patent for their invention, and who knows, a row of such chairs could be provided for the deaf at concert halls in future.

Suranga conducting his study at Dr Reijntje's School for the Deaf