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FEEL SOUND

EXPAND YOUR SENSES

TAD

TACTILE AUDIO DISPLAYS INC.

TIMELINE

1929 – TODAY.
TADs Inc. carries on a historical tradition in developing systems that talk to the body started in the early 1900s. Bell Labs were trying to solve the tactile-sound problem in the 1930s. The TAD system was originally developed to help deaf people feel music, but went main-stream after the first concert that was made accessible to deaf people took off as an international news story [CLICK HERE].

2010: IN THE PUBLIC.
TADs' first system was experienced by over 6.000 people at the Ontario Science Centre, where the research team behind the project conducted user trials, revealing that TADs' system was preferred over D-Box, low frequency bass transducers, and air jets.

2012: RESEARCH SUCCESS. Frank Russo, co-inventor of the original Emoti-Chair publishes his work on on the ability of the human skin to detect different musical instruments when presented on a TAD system.

TODAY: TAD systems are the industry standard for tactile-audio production and entertainment systems.

Vibrafusion Lab (London ON) provides opportunity to experiment with the technology,

CBC classical music blogs reports on the Emoti-Chair a classical music innovation in league with Google Glass.

TACTILE-ACOUSTIC DEVICES (TADS): **Investigating Reduced Drowsiness During Prolonged Attentional Tasks**

Maria Karam, PhD. Kings College London
Patrick Langdon, Cambridge University

ABSTRACT

The study explores whether a tactile acoustic device (TAD) – presenting full spectrum sound to participants through skin contact – can reduce fatigue for drivers over long trips, without compromising performance. After a literature review on the background to sleepiness, a pilot experiment looks at the effectiveness of the Tactile Audio Stimulation. A visual-semantic Stroop test simulates the attention demands placed on a driver during long, boring tasks such as driving on stretches of highway. Test results suggest that a TAD can potentially reduce fatigue for drivers over long trips, without compromising performance.

" To help drivers avoid fatigue, we consider the combination of music with tactile acoustics as a way to provide additional cognitive stimulation"

BACKGROUND

Tactile acoustic devices (TADs) are systems that provide sound information to the body as an assistive technology, augmenting sound with sound vibration [1]. Tactile sounds have been shown to be effective at enabling deaf people to detect musical timbre and emotional aspects of sound on the body. However, if we consider using this technology as a way to increase sensory stimulation, we could potentially increase cognitive stimulation, focus and awareness through the combined and reinforced sense of sound on the skin.

SOMATOSENSORY SYSTEM INTERACTIONS

Haptics target a specific kind of physical sensation, highly effective at representing directional, or spatial notification to the body, as, e.g., as alarms or alerts. However, expanding the tactile signals with additional receptors in the somatosensory system using sound vibrations (tactile acoustics) has been shown to be effective at alerting drivers, for example, to sirens using sound vibrations as an alternative to haptic signals [2]. Tactile sound systems stimulate multiple receptors in the skin to provide a high-resolution tactile-acoustic signal to the body as a means of communicating elements of sound as touch that are subtler than haptics, and that have a much broader range of potential messages and functions [3,4].

EXPERIMENT

The study aims to create a boring yet critical set of tasks that the participant can perform while experiencing the different conditions. A Stroop test was used as the single primary task, asking participants to complete ten correct responses to the test, indicating the colour of the text shown on the screen [5]. If an error occurs, the test starts again until all ten are answered correctly in a row. Participants rate their alertness level both at the start and the conclusion of the experiment using the Karolinska Sleepiness Scale (KSS) [6], which uses a scale of 1 (alert) – 9 (falling asleep). A sheet of paper with the scale printed in large text is located in front of participants during the experiment, and they are asked to pay attention to their ratings while they perform the tasks. Variables include total time, number of errors for each trial, and an alertness variable based on the change in the KSS ratings after completing each trial. The conditions explored in this study are: 1) TAD + Music, 2) Music only 3) Ambient noise as the control.

For the experiment, a set of theatre seats are embedded with a 16-channel tactile acoustic device, provided by the manufacturer [7]. The IPad running a Stroop test application [8] runs and collects responses for the trials. The Stroop test represents the primary task, which we compare to driving a boring road, as one must stay alert, despite the repetitive, seemingly mindless task. The setup is shown in Figure 1, representing a reasonable substitution for an automotive seat.

RESULTS

The results show a significant effect present for the three conditions with respect to the user reports of their KSS after each trial, using a variable measuring the alertness of the participants. Alertness was shown to be significant in the experiment at $p < 0.05$ for the three conditions, showing a positive mean for the TAD condition of .14 (sd 1.9), but negative means for each of the Music (mean -.45, sd 1.7), and the Control condition (mean -.58, sd 1.6) (Figure 2). Individual KSS reports after each trial was also significant for the conditions, revealing a lower report (indicating greater alertness) in the TAD condition (mean 4.17, sd 1.47), compared to the increased tiredness after the Music (mean 4.75, sd 1.45) and the Control conditions (mean 4.88, sd 1.6) (Figure 2). Continued exploration of the data shows a wide standard deviation for the total time variable, suggesting that there may be other factors interacting with the results. Error rates were also shown to be higher in the TAD, but this was not significant in the results.

References

1 Maria Karam, Frank Russo, Carmen Branje, Emily Price, and Deborah I. Fels. 2008. Towards a model human cochlea: sensory substitution for cross modal audio-tactile displays. In *Proceedings of Graphics Interface* 2008 (GI '08). Canadian Information Processing Society, Toronto, Ont., Canada, 267-274.

2 Maria Karam (2013). Evaluating Tactile-Acoustic Devices for Enhanced Driver Awareness and Safety: An Exploration of Tactile Perception and Response Time to Emergency Vehicle Sirens in *Universal Access in Human-Computer Interaction. Aging and Assistive Environments: 8th International Conference*, UAHCI 2014, Held as Part of HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014, Proceedings, Part III". Pages 729—740

3 Karam, M. and Langdon, P. M. Designing Human Somatosensory System Interactions: Not Just for Haptics Any More! in *Designing Around People: CWUAAT* 2016. Langdon, Pat and Lazar, Jonathan and Heylighen, Ann and Dong, Hua. PP 187—196. Doi 10.1007/978-3-319-29498-8

4 Maria Karam (2013). *Multi-modal tactile displays for enhanced driver awareness and safety in Adjunct proceedings of the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (AutomotiveUI '13), October 28-30, 2013, Eindhoven, The Netherlands. Pages 109-110

5 Stroop, John Ridley (1935). "Studies of interference in serial verbal reactions". *Journal of Experimental Psychology18* (6): 643–662.

6 Carter GS. *Sleepfaring: A Journey Through the Science of Sleep*. Arch Neurol.2007; 64(8):1205. doi:10.1001/archneur.64.8.1205.

7 Azmeh Shahid , Kate Wilkinson, Shai Marcu, Colin M. Shapiro. *Karolinska Sleepiness scale* (KSS) in STOP, THAT and One Hundred Other Sleep Scales. Pages 209 -210. November 24, 2011.

8 Tactile acoustic devices provided by Tactile Audio Displays Inc, Toronto, Canada. www.tadsinc.com

FIGURE 1

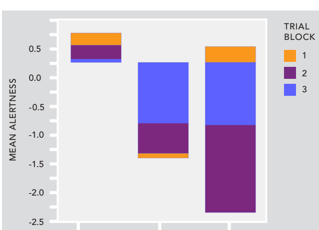


FIGURE 2: Self reports of alertness shows significant effect on trial order and condition, with highest alertness ratings for the TAD condition. Music and Control conditions show no significant difference.

CONNECT

Thank you for stopping by my poster. Please feel free to email me anytime at **maria.karam@kcl.ac.uk.**

Also please feel free to stick a post-it note below (in this box) with your valuable thoughts. Thank you!

GLOBAL MEDIA

TAD'S HIGH-RESOLUTION TACTILE ACOUSTIC DEVICES CREATE A UNIQUE WAY FOR THE BODY TO EXPERIENCE SOUND. TAD has been researching and developing tactile solutions for almost 10 years, providing enhanced entertainment and educational experiences in schools, hospitals, research labs, theatres, studios, and home theatres! TAD develops the technology behind the Emoti-Chair, the world's first technology to bring the sounds of live concerts to the body of deaf, and hearing people alike!

TAD was founded in 2010 to bring cutting edge research in tactile systems to the body in new and exciting systems that enhance entertainment for everyone. TAD systems use a comprehensive frequency range, presenting the full spectrum of audio signals to create the optimal system for delivering true sound to your body! This results in a new sensation of sound that you can feel. TADs can be added to most seats, clothing, and other form factors, to deliver a new experience of sound to the body. Feel everything!

WWW.TADSINC.COM

NOVA, JULY 9, 2014, "Music for Your Skin" by Sujata Gupta
www.pbs.org/wgbh/nova/next/body/haptic-hearing

"Audio-visual technologies have long dominated the media landscape, but touch-based, or haptic, technologies, could soon become more than a novelty."

"Why shouldn't people feel the noises on screen, too… Like Weiser... Fels and her team realized that to convey as much information as possible via the chair, they had to utilize the skin's generous surface area. In a hearing person, sound travels as vibrations through the ear and into a spiral-shaped cochlea covered in tens of thousands of tiny hair cells. Hair cells tuned to hear higher frequencies reside toward the front portion of the cochlea, while those tuned to lower frequencies are embedded deep inside. So Maria Karam, then a post-doctoral fellow in Fels' lab, essentially unraveled the cochlea and arrayed higher and lower frequency "hair cells" across the body by distributing the speakers throughout the chair. "We basically put a speaker on your body and turn your body into an ear," Karam says.

"A closer look at the voice coils on the Emoti-Chair"

GLOBAL MEDIA

CBC MUSIC, DECEMBER 10, 2013, "5 classical music innovations, from Google Glass to Emoti-Chair …"
http://music.cbc.ca/#/blogs/2013/12/5-classical-music-innovations-from-Google-Glass-to-Emoti-Chair

"New technologies in classical music are being used to make music more accessible than ever before. Audiences with hearing impairments can use the Canadian-designed Emoti-Chair to "feel" the sound. Meanwhile, audiences in Kitchener–Waterloo are being asked to turn on their smartphones for an unprecedented guided listening experience."

Discovery Channel (Daily Planet), MARCH, 2009
https://www.youtube.com/watch?v=gA--cOs87p4&feature=youtu.be

"Emoti-chair is a technology that allows us to take sound and present it as vibration along the back with these voice coils."

"… music is far more than sound; it means that people that don't have the ability to hear can still have the experience of music, the emotional experience in particular…"

"Thanks to the Emoti-Chair, Ellen [Hibbard] can now experience the full effects of that rock concert: "'It's great; I can kind of deconstruct the music, and I can feel how everything meshes and it's wonderful because it's new for me, and I like it. I'm starting to understand that music can evoke emotions inside your body, and I thought wow – this is really cool; I'm actually experiencing the emotions that are intended by the person who's composing this music; and it's great because before it was always a physical surface feeling for me and it actually really touched me. It really opened my mind to what music can be.'"

GLOBAL MEDIA

Toronto Life Magazine, DECEMBER 2009, "The Emoti-Chair™, predecessor to the TAD system was voted as #6 of 25 inventions that are changing the world." (page 7)
www.tadsinc.com/Media/New_Technology_changing_world.pdf

"If you're ever watched a horror movie with the closed captioning turned on, you know the shortcomings of the technology. "Scary music plays" just doesn't cut it. The challenge of communicating that sound was the impetus behind the invention of a remarkable new device called the Emoti-Chair. Conceived and created by a team of researchers at Ryerson, the chair translates the beats and pitch of a piece of music into corresponding physical actions and sensations– rocking motions, vibrations, even blasts of cool air to the face–allowing deaf people to feel the emotional tenor of the music. A "concert for the deaf" was held at Bloor Street's Clinton's Tavern last March, with a handful of Emoti-Chairs. An audience of more than 200 was thrilled by the good vibrations.

BBC RADIO4, FEBRUARY 2009, Promoter Launches Rock Gigs for the Deaf
www.tadsinc.com/Media/2009-02-26_BBC4-UK.pdf

"Next week at a rock concert in Toronto two hundred deaf people will take it in turns to use chairs, designed for them to experience the music.The chairs developed by Ryerson University in Toronto analyse sound frequencies and translate them into mechanical responses, including blasts of air, vibration and motion. Using them, deaf people can feel the difference between different music genres, such as classical and jazz."

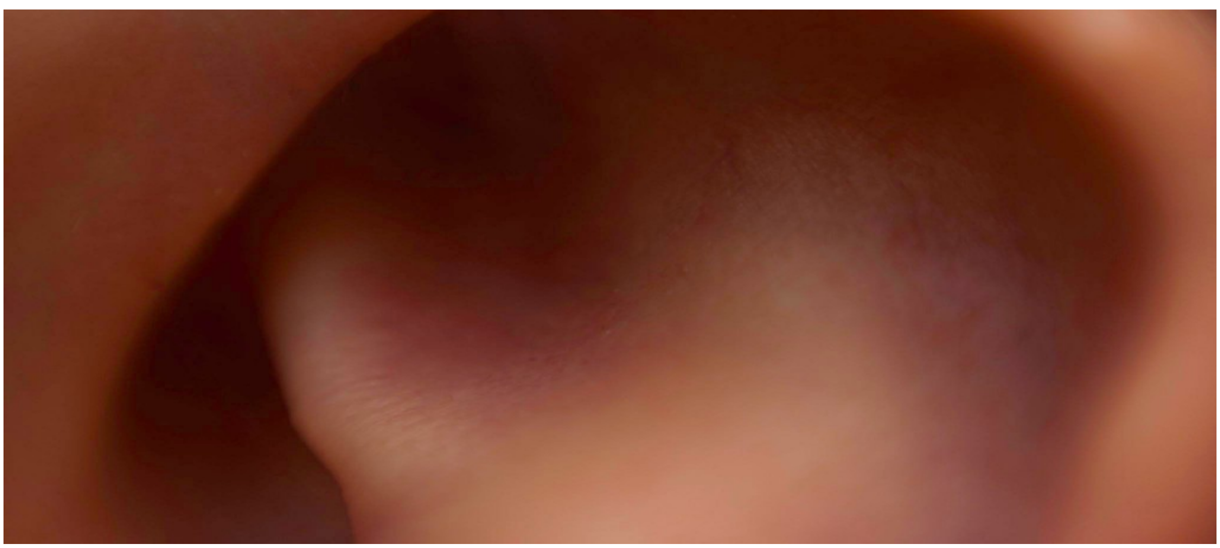
BODY + BRAIN

Music for Your Skin

By Sujata Gupta (http://www.pbs.org/wgbh/nova/next/author/sujata-gupta/) on Wed, 09 Jul 2014

I settle into an orange camp chair that has been stripped and fitted with 16 small, round voice coils, or speakers without loudspeaker cones. Carmen Branje hands me a pair of noise canceling headphones connected to his smartphone and launches a white noise app with instructions to jack up the volume as high as possible. Soon I feel as if I'm underneath a rushing waterfall. Branje hits play on a nearby computer and the chair begins to vibrate, though I can no longer hear the whir. The beat plays fast across my skin, the buzzes fluctuating from soft to intense as they flit up and down my back.

After a few minutes, the buzzing stops and I remove the headphones. Happy or sad? Branje asks. Happy, I respond. Definitely happy.



Researchers are refining tools and technologies to help us hear through our skin.

Audio-visual technologies have long dominated the media landscape, but touch-based, or haptic, technologies, could soon become more than a novelty. As far back as the 1950s, renowned psychologist and tactile researcher Frank Geldard noted that our narrow focus on the ears and eyes ignored other perfectly good channels of communication. The skin, he wrote in 1960, "is a good break-in sense: cutaneous sensations, especially if aroused in unusual patterns, are highly attention-demanding."

Someday we may have a new genre of "music" based not on sound but touch.

Nowadays, with so many gadgets clamoring for the attention of our ears and eyes, using the skin as an alert system has started to gain traction. Cell phones buzz. The handheld controller in Wii vibrates when a user knocks out his opponent in a mock boxing match. General Motors recently installed vibrators inside the seats of its luxury cars to alert drivers when somebody enters their blind spot or when they're drifting too far to one side. Researchers are looking at placing touch sensors along the body to improve bowing technique on the violin, facilitate rehabilitation after an injury or stroke, allow coaches to direct players on the field without yelling, and even help astronauts stay oriented in space.

But here, at the glass-walled Inclusive Media and Design Centre at Ryerson University in Toronto, Canada, the goals are loftier. Branje, who was a week shy of defending his doctoral thesis when I visited, believes our sense of touch can do a lot more than receive alerts. Cell phones vibrate at a single frequency, and so does the buzzer under one's butt in a Cadillac. But Branje, himself a musician, thinks touch can be used to mimic an octave or the feel of a melancholic song. Someday, he says, maybe we'll have a new genre of "music" based not on sound but touch. "Instead of an mp3," he says, "I would send you a vib [vibrational] file."

Hearing Speech Through Skin

Nobel laureate Georg von Békésy, a biophysicist at Harvard University, frequently lamented that those studying hearing, like himself, rarely researched the skin. Békésy's research, inspired by his desire to understand difficult to access parts of the ear via the skin, showed that acoustic elements like pitch, loudness, and rhythm all had touch-based equivalents.

Anatomy backs up his discoveries. The skin is underlain with four mechanoreceptors that each respond to different forms of touch, such as a light tap, pressure, or pain. But in the 1980s, researchers found that those same receptors could respond to—or "hear"—different frequencies. Compared with the tens of thousands of mechanoreceptors in our ears, known as hair cells, the resolution of the tactile system is terrible. But their existence illustrates striking similarities between the two systems.

Much of our early understanding of the skin's ability to receive sound comes from a line of research that blossomed in the 1970s and '80s: enabling deaf people to "hear" the vibrational patterns that make up speech through their skin. That idea first emerged at a deaf school in the 1920s, says Janet Weisenberger, a psychologist at Ohio State University in Columbus, and an early researcher in the field. At that time, researchers essentially affixed miniature loudspeakers to user's hands and fingers, but because the skin can't feel anything above 1,000 hertz—which is where we distinguish among different vowels and consonants—users were able to detect that someone was speaking, but not comprehend what was being said.

Weisenberger and her team have studied a 16-vibrator device that could circumvent the skin's frequency limitations by utilizing its abundant surface area. For instance, Weisenberger arrayed the device across users' arms. A high-frequency note like the sound of the letter "s" would buzz near the elbow while a lower frequency note like "oo" would buzz near the wrist. The name Sue would thus vibrate in quick succession at the elbow followed by the wrist. In that way, people could be trained to recognize the patterns that went along with different vowels and consonants, Weisenberger says. The device "transformed frequency into location."

That finding, coupled with others such as helping users distinguish between words that appear identical on the lips (look in a mirror and say pat and bat) significantly improved the accuracy of lipreading, which alone enables a user to understand a frustratingly low 30–60% of a conversation.

Research into haptic speech could give the deaf greater access to music.

But before the device could reach prime time, another technology soon upended that work. Cochlear implants, which rose to prominence in the early 1990s, reroute sound from the damaged hair cells in the inner ear directly to the auditory nerve. Today, deaf individuals with cochlear implants have greater access to speech and sound than ever before. Funding and interest in haptic speech soon dried up. Yet the information gleaned from that work could serve another purpose—giving the deaf greater access to music.

Even those with cochlear implants stand to benefit. Most cochlear implants have been made to maximize an individual's ability to hear speech, which is much less dynamic and occupies a narrower frequency range than music. A soprano may sing four octaves higher than her speaking range, for instance. In an essay titled "My Bionic Quest for *Boléro* (http://archive.wired.com/wired/archive/13.11/bolero.html)," that appeared in *Wired* magazine in 2005, writer Michael Chorost writes about his experience with his first implants. "I could hear the drums of *Bolero* just fine. But the other instruments were flat and dull. The flutes and soprano saxophones sounded as though someone had clapped pillows over them. The oboes and violins had become groans. It was like walking color-blind through a Paul Klee exhibit."

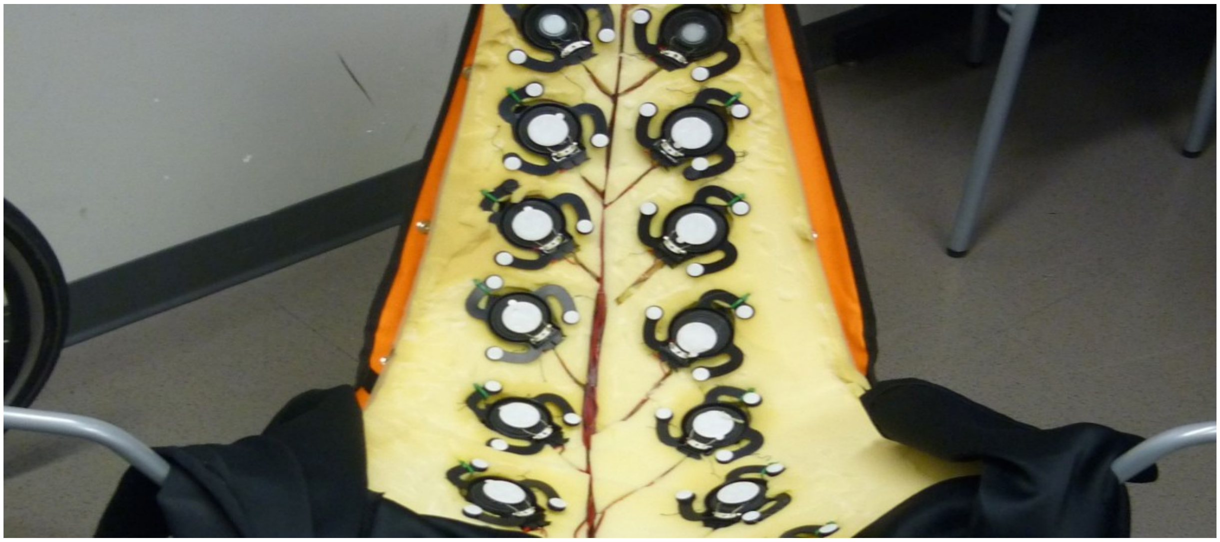
Feeling the Horror

The “scary scene” from the movie *The Sixth Sense* runs for almost two minutes without dialogue. In it, a young boy comes face-to-face with the ghost of a girl. She is puking violently. The boy screams and runs. He is breathing heavily and sobbing. Eventually, though, the boy returns to the girl and offers his help. The music starts off low and slow, then crescendos when the boy first encounters the girl, before fading again. As a viewer, I’m terrified right alongside the boy. But then I watch the scene a second time—on mute. Almost immediately, I’m bored. What, after all, is a scary movie without scary music?

Deb Fels, Branje’s thesis advisor and head of the Inclusive Media Center at Ryerson, has dedicated her career to making media more accessible to people with disabilities. Several years ago, Fels, began addressing the shortcomings in relaying sound in film and television to deaf and hard of hearing audiences. Closed captioning, she says, is usually handled not by the creative team, but outsourced to people who have nothing to do with the show. “You get crap,” she says. “You get spelling mistakes, grammar mistakes, missing stuff, and that’s how deaf people consume that particular piece of media. They don’t have any alternatives.”

“We basically put a speaker on your body and turn your body into an ear.”

Fels set out to change that. In the late 2000s, she and her team designed and began testing the Emoti-Chair, the same chair I sat in. Why shouldn’t people feel the noises on screen, too, they thought? Like Weisenberger, Fels’ team realized that to convey as much information as possible via the chair, they had to utilize the skin’s generous surface area. In a hearing person, sound travels as vibrations through the ear and into a spiral-shaped cochlea covered in tens of thousands of tiny hair cells. Hair cells tuned to hear higher frequencies reside toward the front portion of the cochlea, while those tuned to lower frequencies are embedded deep inside. So Maria Karam, then a post-doctoral fellow in Fels’ lab, essentially unraveled the cochlea and arrayed higher and lower frequency “hair cells” across the body by distributing the speakers throughout the chair. “We basically put a speaker on your body and turn your body into an ear,” Karam says.



A closer look at the voice coils on the Emoti-Chair

When I watch the scary scene from *The Sixth Sense* on mute from the chair, the effect is electrifying. Soft buzzes flit across my lower back during those initial creepy moments and then the whole chair vibrates intensely—the crescendo—before returning to the low frequency buzz. To see how scared people could get by just feeling the vibrations, the Ryerson team had 59 volunteers sit in the chair and watch clips from both *The Sixth Sense* and *The Shining* while they measured their galvanic skin response, or GSR. GSR is the same physiological response measured during lie detector tests; it spikes whenever a person is agitated. They found that the participants' GSR blipped during suspenseful scenes, or when the chair's vibrations were more muted, but soared when participants were startled—like when the boy in *The Sixth Sense* encounters the puking girl. The chair, says Branje, can "give you those tinglies without sound."

The Deaf Concert

Until the birth of his daughter a year and a half ago, Branje played percussion in a punk band. On a recording he sent me, the music is metallic and gritty.He's always loved music, Branje says, and he grew up playing the piano, but his obsession was computers. As an undergraduate computer science major at Ryerson several years ago, Branje stumbled across an ad Fels had placed for a research assistant. She wanted someone to create software to add an additional layer of narration to film and television for blind viewers. Branje liked the work, so instead of going directly into industry after graduation as was his plan, he became a graduate student in Fels' lab.

Branje soon started working on the Emoti-Chair, the timing of which coincided with his punk band days. Snagging gigs and playing in front of live, throbbing audiences became part of his new reality. His work in Fels' lab, though, left him wondering what it would be like to lack access to that world. So in 2009, Branje lined up four bands and a DJ and hooked up five chairs to the sound system. Rather than playing high and low frequencies along different parts of the back, the various instruments and vocals were funneled to different speakers inside the chairs.The event, billed as the first deaf-accessible concert, became a media sensation.

Yet Branje wanted more. Even though many deaf listeners felt inspired, Branje knew the sounds they were feeling were a watered-down version of the real thing. He wanted to devise a system designed specifically for touch. Branje set to work creating a keyboard, one that didn't play sound but instead funneled vibrations to the Emoti-Chair, a project that became the cornerstone of his doctoral work. When Branje thinks big, he sees his work as not a way of just presenting music to the deaf, but an entirely new art form accessible to all. Paintings appeal to the eye; music appeals to the ear; vibrotactile music appeals to the skin.

Composing Vibrotactile Music

Yet transferring music to skin is far from straightforward. Part of the problem is speed. The human ear, which has evolved to respond immediately to an external threat, is capable of hearing auditory changes that happen over just a few microseconds, yet the skin takes milliseconds. It's glacially slow by comparison, says Roger Cholewiak, a haptics researcher who retired from Princeton University in New Jersey in 2004. "*The Flight of the Bumblebee* may not be well appreciated on a tactile display."

But music that is too slow will cause the skin to adapt or tune out the vibration. A person will notice the feel of a shirt when she first puts it on but will get used to it in less than a second," Cholewiak says. Moreover, not only does the skin "hear" at a much lower frequency than the ear, it also struggles to discern between notes that are very close in pitch, like adjoining keys on a piano. That discernment gets worse the higher the frequency.

"Vibration is always there when we're close to the music-makers."

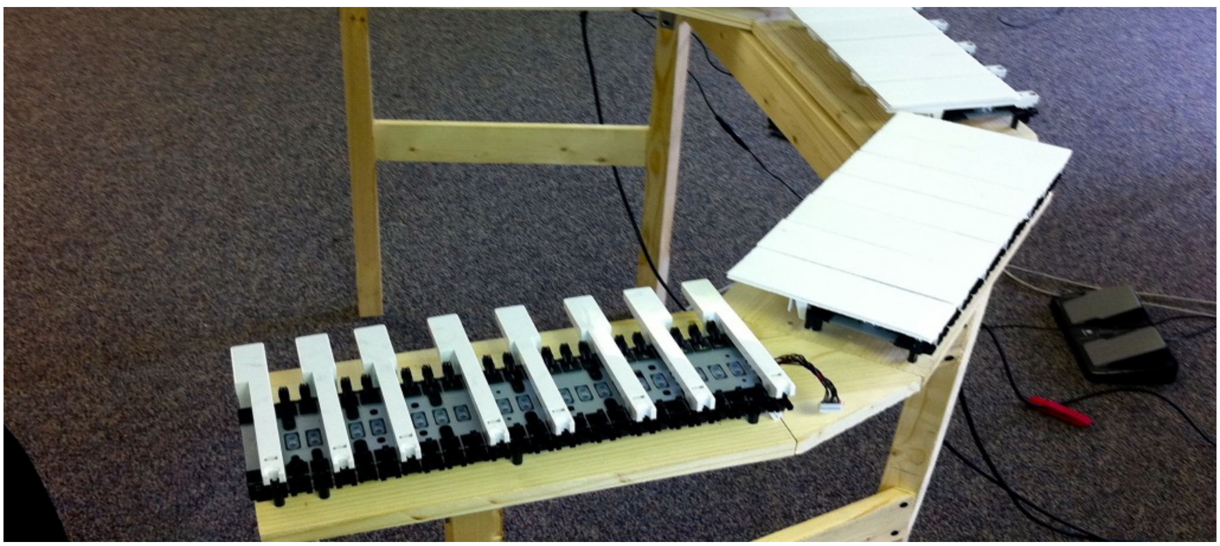
Altogether, that suggests that vibrotactile music must be low in frequency, slow, but not too slow, and dynamic—but only to a degree.

While the challenges are indeed daunting, Frank Russo says the payoff could be profound. Russo, a cognitive neuroscientist at Ryerson and co-inventor of the Emoti-Chair, is interested in how we perceive sound outside the ear. He's found, for instance, that the skin can discern timbre, which is to say it can feel the difference between instruments like a violin and a piano even when they are playing the same note at the same loudness. For Russo, touch and sound are fundamentally related.

"Vibration is always there when we're close to the music-makers," he says. "But for at least a hundred years we've had recorded music and we've had the opportunity to be removed from the music makers." Reuniting what we feel and what we hear, then, could, at the very least, make the experience of listening to one's radio in the living room considerably more exciting.

Reawakening Our Tactile Sense

Back at the lab, Branje plays me another tune. This one is slow and starts very low along my back. It clearly feels sad. The tunes were composed on Branje's keyboard, which doesn't look much like a normal keyboard. It is large and shaped like a semicircle so that composers can always feel the pulse against their back. The keys themselves are divided up into five sections, each of which map to different sets of voice coils in the Emoti-Chair, and each section has eight keys ranging from 40 to 421 hertz. So if Branje taps the 40-hertz key at the left-most section of the keyboard, a person sitting in the chair would feel a low-pitched buzz along their lower back. If Branje hits the same 40-hertz key on the far right of the keyboard, that same buzz would play along the shoulder blades.



Branje's custom keyboard activates the voice coils on the Emoti-Chair.

Once he had created a prototype for the keyboard, Branje set out to see how he could convey the emotion typically found in music through touch. Some aspects of music, Branje says, transfer perfectly from ear to skin, such as rhythm and tempo, though he suspected other elements would prove more challenging. For instance, in Western music, major keys connote happiness, while minor keys connote sadness. But what would the equivalent of songs written in major and minor keys feel like? It's a black box, Branje says. "There is no such thing as a vibrotactile song."

To begin sorting it out, Branje asked professional music composers to write happy or sad vibrotactile songs. Someone who had spent years conveying emotion via sound might intuitively understand how to convey those same feelings through touch, he reasoned.

His early results are promising. When Branje played those compositions to volunteers and had them report what emotion they thought the songs conveyed, they often reached the same conclusion. Branje then broke down each composition by musical elements, such as tempo, amplitude, frequency, length of individual notes, and how often a piece jumped along tracks (or speakers along the back). He found that tempo, or the number of notes per second, and frequency had the greatest significance. “If you use a higher frequency and a higher tempo people are going to think your songs are happier,” he says.

With his doctorate now complete, Branje now has a full-time job in industry. But his keyboard remains in use. Recently, it, along with several chairs, were hauled two hours southwest, to London, Ontario. There, at the new VibraFusion Lab, visiting artists can learn how to incorporate touch into their work. Rather than teach the finer details about how the skin works, the specifics of which are still being sorted out anyway, David Bobier, the artist heading up the lab, suspects people will discover its limits through experimentation. But he also hopes that the process will reawaken people to the beauty of touch. “We are,” he says, “tactile people who have been numbed by our other senses.”

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Other posts from this contributor (http://www.pbs.org/wgbh/nova/next/author/sujata-gupta/)

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