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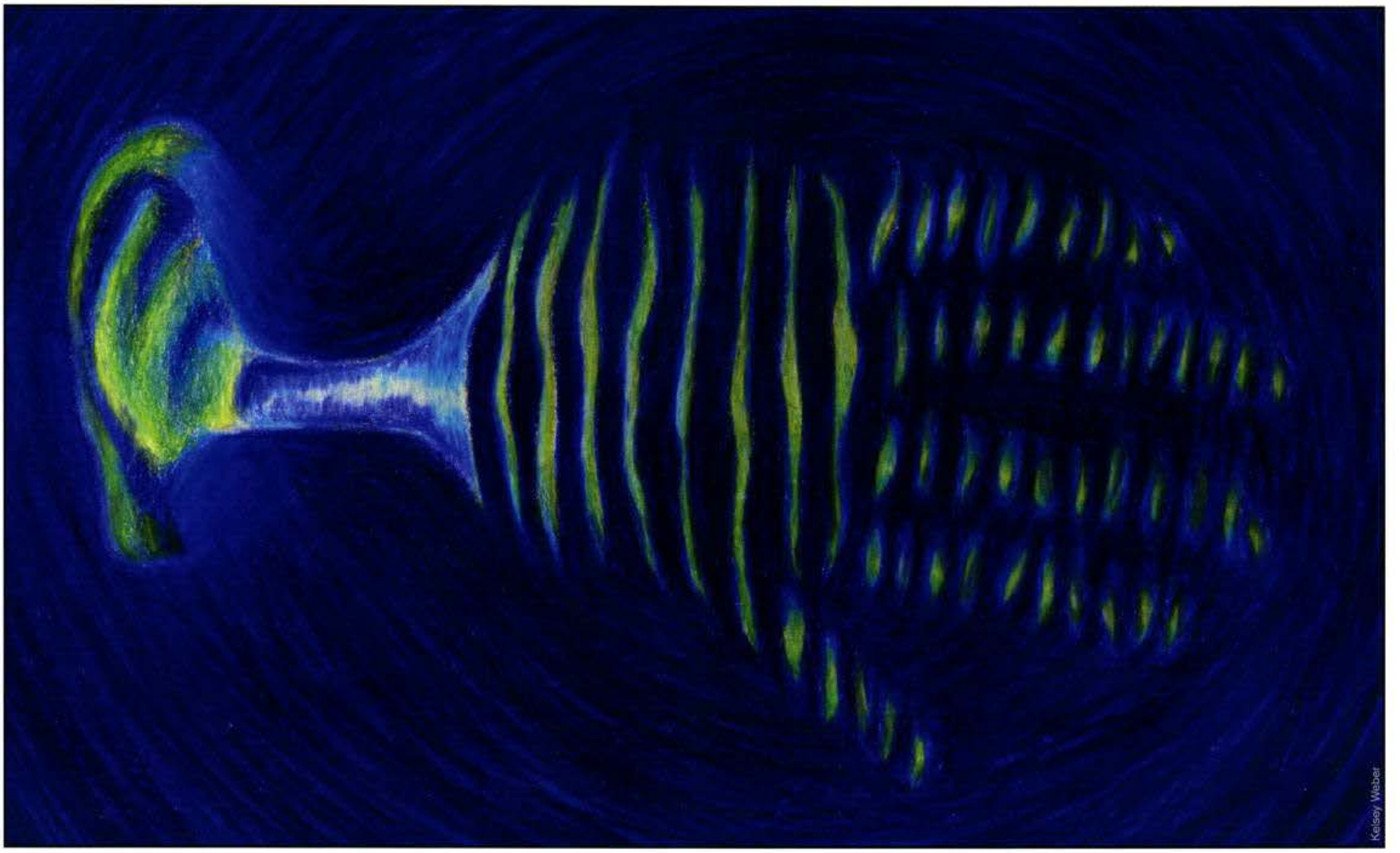
Adrian Jewell



Frontiers of Cross-Modal Display:
The *Emoti-Chair* as a Model Human Cochlea

By Adrian Jewell

At Ryerson University, the laboratory of psychologist Frank Russo has developed the technology to convey musical emotion through vibrotactile stimuli. Cleverly named the "Emoti-chair", the apparatus channels vibrations through the seat via embedded speakers. Ultimately, the participant feels, rather than hears, the music.

Many have already experienced such phenomena, but more as a supplement to our acoustic experience. One may have, for instance, attended a party where the beat of the music, in addition to being heard, could be felt, coursing through the body. Additionally, one may have relaxed into the massaging vibrations and ambient soundscapes of a spa chair. Another way to take advantage of the cross-modal display is to watch the iTunes visualizer.

The visualizer takes the structural content of the sound recording to produce a visually stimulating animation. These examples demonstrate that today's commercial cross-modal technology is readily available, but primarily supplementary. While the aforementioned recreational experiences with vibrotactile information supplement and enhance the music going through the ears, Russo aims for a freestanding musical experience that can be felt on the body.

One's intuition may offer an easy solution to this goal: simply output the composite audio signal of a song through speakers, then touch the speakers. This will likely cause a general buzzing sensation. Where's the emotion? The problem is that the small patch of skin that touches the speaker cannot discern the intricate patterns of sound. This is because the ear is far superior to the skin in sensitivity to vibrations. It can hear from 20 Hz to 20,000 Hz, while the skin senses within the range of 5 Hz to 1,000 Hz. As such, pitches must not only be translated but also manipulated to fit within the skin's sensitivity range.

The solution, therefore, is to decode sound into its component layers and present them in such a way that we perceive all of them simultaneously. For a solution, researchers analyzed the human cochlea, an organ in the auditory system that resembles a spiraled sea shell and naturally deconstructs complex sound into its component parts. The cochlea decodes complexity in sound waves by separating the derivative frequencies along its length. For example, high frequencies in the sound activate the entrance to the cochlea, and the bass frequencies activate the center of the spiral. This is the process of place coding, a central feature that will allow researchers to translate sound into another sensory modality.

A structural analysis of melody will better explain the importance of place coding. Consider the physical properties of melody.

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A sound that ascends in frequency corresponds to a rise in pitch. Similarly, a lowering of frequency corresponds to a lowering of pitch. The dynamic qualities of frequency provide emotional content related to the patterns of changes in frequency. Remember that a rise in pitch means a change in place code in the cochlea. It may be that people seem to hear pitch at different locations because the cochlea actually registers different pitches at different locations. This is why a deep grumble can emerge from the ground, and a beautiful, luminous melody can seem to "descend from the heavens." This considered, location frequencies can be placed along a gradient, with the higher frequencies closer to the head and lower frequencies nearer to the lower back. When researchers map pitches in this way, one can effectively translate a melody, as if the human body itself were the cochlea: thus, a model human cochlea (MHC).

Designing the chair poses a considerable challenge. First, researchers do not yet have the technology for a body "pad" on which one could present any conceivable vibration at any conceivable point. The substitute consists of specialized speakers embedded into the back of the chair. These speakers, coined "voice-coils", are organized into rows and columns down the back. The prototype design went through several phases. The current model includes voice-coils down the entire back as well as some smaller ones in the arm-rest.

Two models currently exist to utilize the advantages of the MHC: Track Model (TM) and Frequency Model (FM). TM is the process by which a multi-track master recording is channeled through the voice-coil configuration. TM tracks can be created by recording each layer of music individually. FM is the method used to deconstruct composite sound files into segmented audio tracks based on frequency. Note that it does not separate tracks, but frequencies. For example, in a piece of music that uses a drum set, some parts of the drum set will be high frequency and other parts will be lower. These two components of the sound will end up on different audio tracks. To clarify further, if one were to play all the resulting frequency tracks at the same time, one would hear the original piece of music. The resulting frequency bands are channeled through corresponding voice coils. In an ideal world, a TM would be reconstructed from a composite sound file.

The first official study on the Emoti-chair sought to test FM as an effective way to apply sound to the MHC. Researchers asked, "Does the FM method convey emotion better than a control method?" They found that it did, but a portion of the results were controversial. Participants experienced eight different audio samples through the Emoti-chair both with FM processing and in a control situation. In the control, the sound was transmitted through the chair without place coding. The selections were chosen to cover a swath of emotions (joy, anger, fear, and sadness). After the participants experienced the sample, researchers measured three things: valence (amount of positive energy), arousal, and enjoyment. Additionally, researchers asked for specific comments on the chair.

On average, participants rated the samples in FM as having stronger valence than the control method. More specifically, valence ratings did not differ significantly between joyful and sad music. This is to be expected, because joyfulness and sadness are two high-valence emotions on the circumplex model of emotion. This reflects Emoti-chair's still primitive qualities. On a more positive note, the mean enjoyment ratings for joy were significantly higher than those of sadness and anger. Enjoyment ratings for sad music also topped those for anger and fear. This is also an expected result because sadness is actually a very popular style across genres. Just imagine how many popular songs and non-vocal works are laments, ballads, or pieces with qualities of pain and sorrow. The reason that joyful music carries a comparably high enjoyment rating may be for reasons intrinsic to the qualities of the FM, rather than just the music itself. Joyful music typically has a wider range of frequencies as well as more rapid movement and development of musical content. A more varied, and therefore more stimulating, set of frequencies might just feel more arousing. The researchers endorse this opinion.

The subjects provided qualitative remarks on the selections. As a general remark about the FM selections, one person said, "I'm enjoying the track with a wide range much better than the one that stays within a tight range." This should be expected of FM tracks, which present a wide range of frequencies across the back. Participants described a selection from FM-Fear as "military, urgent, impatient" while the same track as a control was "boring, didn't say anything." Other comparisons between FM and control had less clear distinctions. A control selection for joy ranged from "too low, too weak to express anything" all the way to "epic, energetic, and proud." In spite of these examples, it was still observed that participants more clearly characterized their emotions after FM experience than after experiencing a control stimulus, suggesting a more vivid comprehension of emotional experience.

Ultimately, the Emoti-chair provokes a philosophical re-contextualization of music. In the past, music meant sitting in a hall with only acoustic amplification. Now, venues have multimedia presentations and amplification technology. In the future, one may don a bodysuit of vibrotactile stimulators. With this garb, Mozart might blissfully massage while metal or filthy dubstep may grind one's innards. One should consider the question of whether quality of musical experience improves with technology. This invention suggests that music may eventually synthesize the senses into one conglomerate modality; already, those without hearing disabilities describe listening to music with the Emoti-chair as immersive.