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What music reveals about the human brain

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EU-funded researchers are uncovering how music shapes the brain, paving the way for advances in medicine, education and brain-computer technologies.

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By Maria Vlastara*

During conversation, our brains are constantly predicting which word comes next. That ability helps us understand speech in a noisy café or anticipate a friend's next sentence. This skill for prediction is also linked closely to our enjoyment of music.

For Professor Shihab Shamma, an auditory neuroscientist at the École Normale Supérieure in Paris and the University of Maryland in the US, understanding how the brain processes music is a central research question.

Between 2018 and 2025, he led NEUME, an EU-funded project investigating what music can reveal about how the brain learns, predicts and adapts.

"Language has an obvious purpose," he said. "Music is different. We can survive without it, but life would be very different. It engages the whole brain, yet we still don't completely understand why humans developed it."

For centuries, philosophers, musicians and scientists have debated why humans make music. Every culture has its own musical traditions, yet no single explanation fully captures music's profound effect on us. Rather than simply asking why people enjoy music, the NEUME team asked a broader question: what can music teach us about the human brain?

Music as a window into the brain

Shamma has spent much of his career studying how the brain processes sound, particularly speech. Music, he says, presents a fascinating challenge because it shares many properties with language while remaining uniquely human.

“Music is a very special acoustic signal,” he explained. “You can immediately recognise it as music rather than speech or environmental noise. Somehow, it has properties that engage perception, memory, emotion and cognition all at once.”

Unlike everyday conversation, musical structure can be described with remarkable precision, allowing researchers to study prediction and learning in ways that are difficult to achieve with language alone.

The researchers wanted to understand how music shapes the brain across very different timescales, from a lifetime of listening to fractions of a second. Years of listening teach us the musical “rules” of our culture, while every note creates an almost instant prediction of what comes next.

“It can happen over your whole life,” said Shamma. “But it can also happen within a few notes. Those are very different timescales, and we wanted to understand them all.”

The music of silence

One of the project’s most striking discoveries came from an unexpected place: silence. Giovanni Di Liberto, assistant professor at Trinity College Dublin, joined the team as a postdoctoral researcher after studying how the brain processes speech in noisy environments.

Working alongside him was neuroscientist and trained violinist Claire Pelofi, now at New York University, whose musical background helped shape many of the research questions.

Music provided an ideal way to study prediction because, unlike language, its structure can be modelled with remarkable precision. Di Liberto brought expertise in decoding complex brain signals, while Pelofi brought the perspective of a trained musician, helping design musical stimuli that preserved musical structure while remaining suitable for computational analysis.

“Having a background in music theory means the questions are

already there," Pelofi said. "As a musician, you spend years wondering why certain moments create tension, resolution or emotion."

Di Liberto's work focused on predictive processing: the idea that the brain constantly learns patterns and uses them to anticipate what will happen next.

"Our brain is constantly learning patterns," he said. "Music can't be too surprising, but it can't be too predictable either. Otherwise, it becomes boring."

Instead of studying only the notes people heard, the researchers looked at what happened when no note was played at all. Using electroencephalography (EEG), a test that measures electrical activity in the brain, they discovered that the brain remained highly active during pauses in music. When listeners expected the next note, their brains generated measurable signals even though no sound had reached their ears.

"The silence lets us isolate the prediction," Di Liberto explained. "Normally, you observe the brain's response to the sound together with the corresponding prediction. During silence, you see only the brain's expectation."

The team then asked musicians to imagine familiar melodies without hearing them. Many of the same brain mechanisms became active, showing that imagined and heard music rely on similar predictive processes.

These "Music of Silence" studies have since inspired researchers worldwide, while earlier work showed that the brain tracks the grammatical structure of music, opening new ways of studying musical expectations across cultures.

The researchers also found that the brain rapidly adapts to unfamiliar musical systems, offering fresh insights into how we learn entirely new patterns, with implications that may reach beyond music into language and other forms of learning.

From melodies to medicine

Although rooted in fundamental research, the findings could have applications far beyond music. Disruptions in predictive mechanisms are linked to conditions such as autism, dyslexia and schizophrenia, while advances in brain-computer interfaces

are bringing the reconstruction of imagined speech – and even imagined music – closer to reality.

The team's openly shared datasets and analytical tools are also helping other researchers build on these discoveries.

Shamma believes the field is advancing rapidly. "Decoding imagined speech or music non-invasively is becoming increasingly realistic," he said.

Such technologies could one day help people who have lost the ability to speak communicate using their thoughts alone. They may also support educational tools capable of providing personalised feedback while students learn music or languages.

For Pelofi, however, years of studying music have not diminished its mystery. "The more we understand how music works, the more fascinating it becomes," she said. "We can explain surprise, expectation and emotion with increasing precision, yet there is still something deeply powerful about music that remains elusive."

For Shamma, the project's greatest contribution is showing that music offers one of the clearest windows into how the brain learns, predicts and adapts.

"Music is universal," he reflected. "Every culture expresses it differently, but people everywhere respond to it."

By understanding why a melody lingers long after the final note fades, researchers are revealing fundamental principles of learning, prediction and imagination: the very things that help make us human.
