Hopkins scientist finds link between neurobiology of music, language

Researcher Charles Limb tracked the areas of the brain that light up and shut off when jazz pianists are improvising

Brain scientist Dr. Charles Limb, in his lab at Johns Hopkins, where he studies the brain and how music interacts with the brain. Mike Pope, a jazz musician, was one of Limb's research subjects. (Lloyd Fox, Baltimore Sun photo / February28, 2013)

By **Mary Carole McCauley**, The Baltimore Sun

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A Johns Hopkins brain scientist is finding a neurological basis for a notion that many people believe intuitively — that music is as much a form of language as Spanish or French.

Charles Limb is one of just a handful of researchers worldwide studying what's going on in the brains of jazz musicians who compose on the fly.

Some findings related to traditional language areas of the brain are what Limb expected to discover, though one key and recent result has surprised even him. But he's hoping that what he's learning may apply to creative activity and problem-solving of all sorts — whether writing a novel, designing a better mousetrap or devising a mathematical proof.

Twice in recent weeks, Limb has talked publicly about his newest findings: once to his fellow scientists attending a conference of the Association for Research in Otolaryngology in downtown Baltimore, and the second time to a group of artists, cultural leaders and lawmakers at the Maryland Arts Day celebration in Annapolis.

"The brain on arts is different than the everyday brain," Limb says.

"I'm using music as a starting point to ask, 'How do we create something new?' That's a really basic question of human existence. Creative activity is linked to basic mechanisms of problem-solving, innovation, evolution and survival. If we could unlock the key to creativity, think about what that could mean for civilization."

Limb has been a serious musician all his life. His main instrument is the saxophone, though he also plays piano and bass. When he attended college at Harvard University he directed a jazz band. He's a member of the Peabody Conservatory faculty, where he works with students interested in music cognition.

But when Limb was in college and trying to commit to a career, he arrived at a crossroads. "I couldn't figure out what to do," he says. "I had a deep love of music, but I also had abilities in science. I finally decided that to pursue a professional career in music would be self-indulgent because I wasn't good enough to transform the art. Then I realized that the reasons I liked music are very much the same reasons I was attracted to medicine. Both deal with the essential stuff of life. Medicine is almost the physical embodiment of music."

After graduating from medical school at Yale University, Limb completed his residency at Hopkins, and then two postdoctoral research fellowships at Hopkins and at the National Institutes of Health in Bethesda. It was in 2003, while he was at NIH, that Limb began trying to capture the mysterious, ephemeral moment when an artist or inventor dreams up something that has never before existed.

"Art is magical, but it's not magic," Limb says.

"It's a neurological product, and we can study this neurological product the same way we study other complex processes such as language. The goal isn't to oversimplify or to reduce music to a series of synapses. It's almost like peering into the window of a house and trying to understand the lives of the people who live inside. You can only get so far."

He decided to study jazz performers, not only because that's an art form he loves, but also because it's a genre in which bursts of inspiration take place in public. Jazz players improvise in noisy, crowded clubs, amid the distractions of people slamming doors or the wailing siren of a passing ambulance.

Given that environment, Limb's 30 subjects, all jazz pianists, haven't so much as raised an eyebrow at being asked to conjure up a new composition under decidedly unusual circumstances. So what if they're plunking away on a miniature digital keyboard that they can't look at directly, while lying on their backs and being simultaneously wheeled into a claustrophobia-inducing metal tunnel?

"It was unorthodox," says one of Limb's subjects, the Baltimore-based pianist Mike Pope. "But we've all had to deal with situations in which it was equally difficult to make music. It's just as hard to play in a club when people are watching a football game and the blenders are running."

Limb's main tool is an fMRI, or functional magnetic resonance imaging unit, that uses electrodes strapped to the pianists' heads to measure the blood flow in different parts of their brains. The pianists' legs are propped over a triangular-shaped bolster. The 35-key, digital lap keyboard that it took Limb two years to design rests on their thighs. Two attached mirrors allow the pianist to see the keyboard right side up. When a musician depresses a key, it sounds a corresponding note on a computer outside the scanner.

Before coming into the lab, the pianists had learned a12-bar blues song that Limb had written. A recorded quartet performing in the background played the chord changes. After playing the piece as written, the pianists were asked to improvise on the chord changes.

When Limb later analyzed their brain scans, he found something interesting: "Our key finding is that the part of the brain called the prefrontal cortex really changes its neurobiology when you're improvising as compared to when you're playing memorized music," he says.

"The part that turns on when you're improvising is the medial prefrontal cortex, the sort of semi-autobiographical area that's linked to things like self-expression. The part of the brain that turns off is called the dorsolateral cortex, and it's linked to inhibition.

"So during creative playing, you get this combination of self-expression with the absence of conscious self-monitoring. We think that's how jazz musicians are able to improvise."

Limb is quick to add that it's just one study. Nonetheless, his hypothesis squares with Pope's experience performing. "When you're censoring yourself, playing the notes feels physically different," Pope says. "There's a kinesthetic change. Your body tends to feel inexplicably heavier. It's as if your brain is fighting with your central nervous system and trying to control your movements.

"But when you're in the zone, it just feels easy. It feels just like breathing or talking. It feels so natural it almost seems not profound. You think, 'Can't everybody do this?' "

Limb also was wondering what happens in musicians' brains when they're communicating musically. So for his next study, he wired up 12 jazz pianists and sent them back into the fMRI with the digital keyboard. But this time, Limb sat in the scanner room in front of a keyboard of his own. He and the pianist began "trading fours" — a jazz term for a call-and-response musician sequence in which two solo instruments alternately play four measures apiece.

The results from this study are still so new that Limb is preparing them for publication. What he found was that when the pianists were conducting a musical conversation, two areas of the brain that are involved in understanding language and in speaking — respectively "Wernicke's area" and "Broca's area" — lit up and showed rapid-fire bursts of activity.

"These findings indicate that when musicians are communicating with one another, they're invoking classical language areas of the brain, even though they're not speaking," Limb says.

This outcome wasn't unexpected — but another finding was. It concerns the angular gyrus, a part of the brain involved in semantics. It seems while the musicians were engaged in their musical back and forth, the amount of energy they spent deriving meaning from words dropped off sharply. "The differences were highly significant," Limb says, "and to me, this calls into question how language is implemented in the brain."

"Maybe our concept is too narrow. Maybe Broca's and Wernicke's areas aren't specific to language. Maybe they're specific to communication. This finding also provides a possible link — a strong link — between the neurobiology of music and language."

Though many scientists worldwide study the biological basis of music, just a handful (Limb, a team in Sweden, and Aaron Berkowitz, a Boston-based pianist and neuroscientist) are focusing on improvisation. Coincidentally, Berkowitz published a paper about his findings the day after Limb first published his. Berkowitz says that his experiments and Limb's complemented each other, almost as if the scientists had unknowingly been trading fours. As he explains it, Limb mapped out the forest, while he described in detail a few particularly interesting trees.

Limb looked at the whole brain, and found more than 40 areas that were active during improvisation. In contrast, Berkowitz homed in on just three areas related to generating new ideas, making decisions and planning physical movement.

Berkowitz was impressed that Limb sidestepped a common pitfall for brain scientists, who are frequently criticized for studying their human subjects in a laboratory instead of in the real world. "Charles had real jazz musicians playing real jazz," Berkowitz says. "He replicated the real world in the lab, and that's something that's very challenging to do."

Unlike, say, a drug trial, conclusions reached by brain scientists are rarely determined to be true in the way that most people think of definitive proof, Berkowitz says. But, those conclusions also are never really shown to be wrong.

It's a little bit like the folk tale about the blind men examining the elephant. The number of musicians studied might be small, but Limb's brain scans show what they show. Future studies might refine his results, but they won't discredit them altogether. If in the end, all that Limb ends up describing is the elephant's tail, he might not have an understanding of the whole animal, but he has still identified an authentic, working part.

He hasn't stopped to consider the practical implications of his findings; he will leave that to future theorists. Not that Limb is planning to stop his explorations any time soon. He's already embarked on studying other art forms improvised before a crowd, such as freestyle rap and caricature sketches. He's curious about the role that emotion plays during creativity.

"I have a lifetime of experiments planned in front of me," he says, "and I don't ever expect to get to the end."

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