

# *Creativity and the Brain*

Phillip L. Pearl, M.D.

Longwood Symphony Orchestra

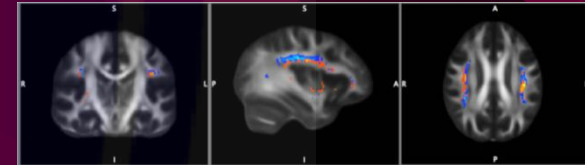
Music and Health Institute, Berklee College of Music

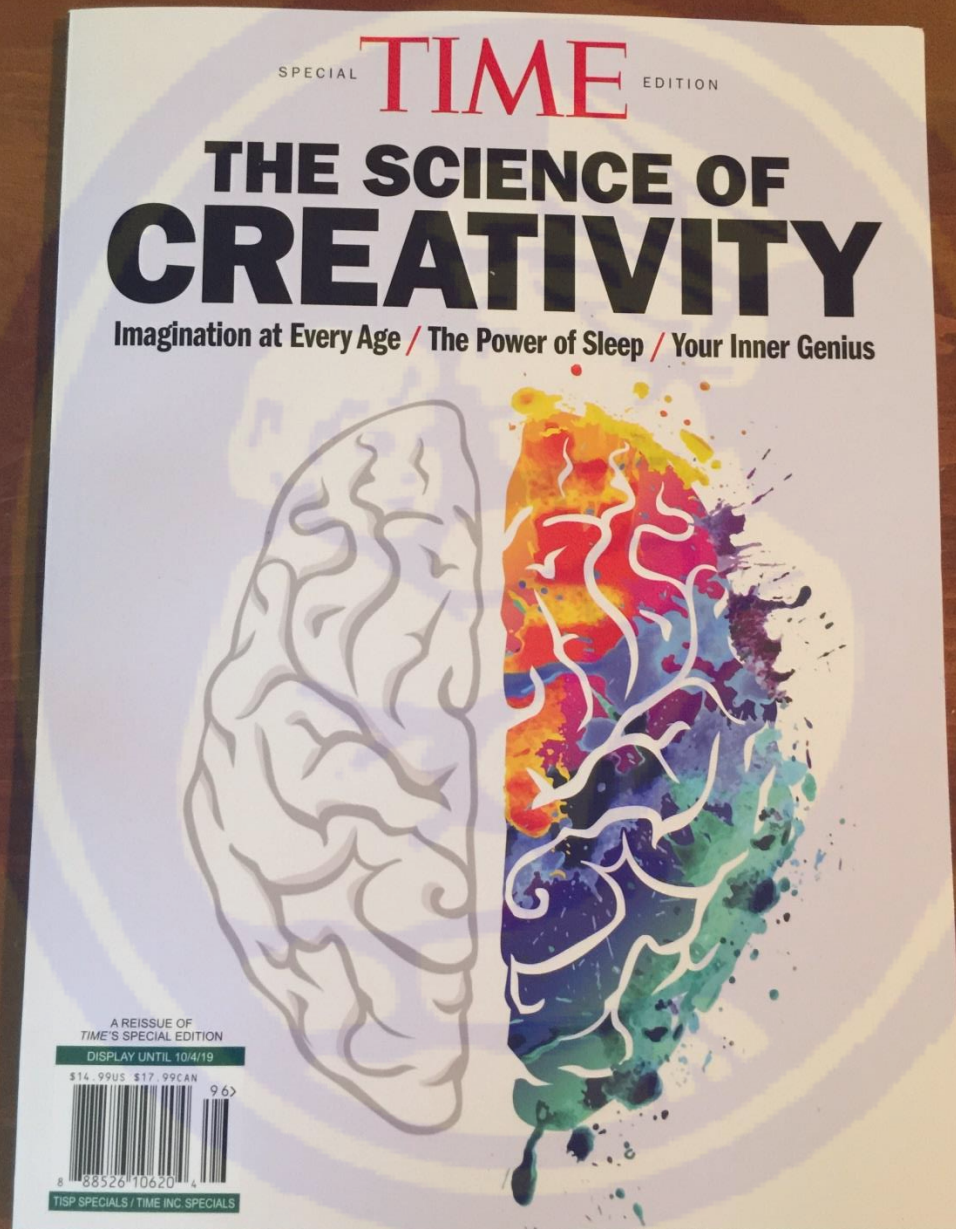
Director, Epilepsy and Clinical Neurophysiology

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William G. Lennox Professor of Neurology

Harvard Medical School

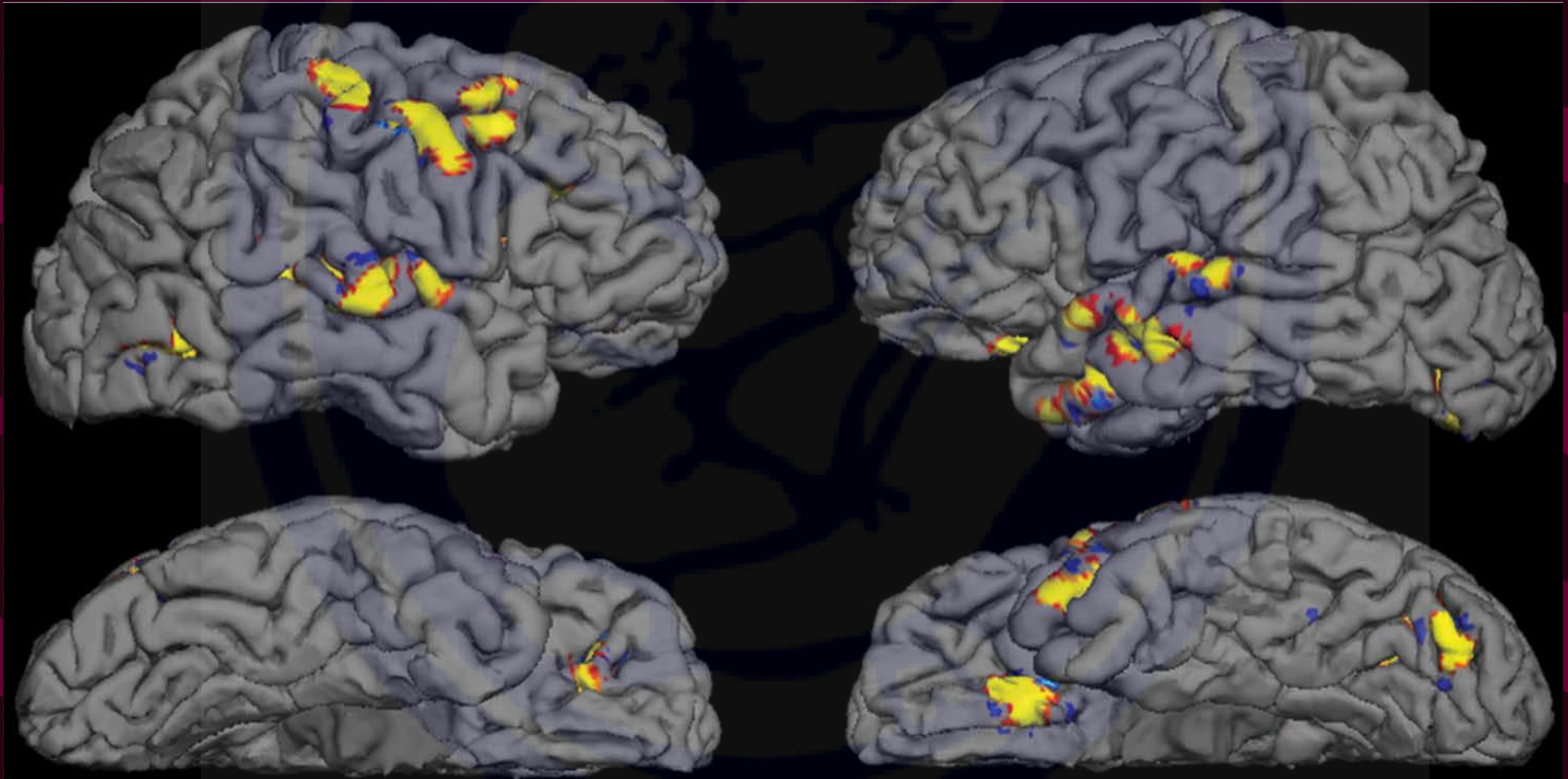




# Creativity and the Brain

- What is the neurological substrate of creativity?
- Why does the brain seek creativity?
- How do we acquire creativity?
- What factors disrupt creativity?
- Can creative behaviors be learned?
  - Charles Limb MD, Johns Hopkins Hospital, Balto, MD

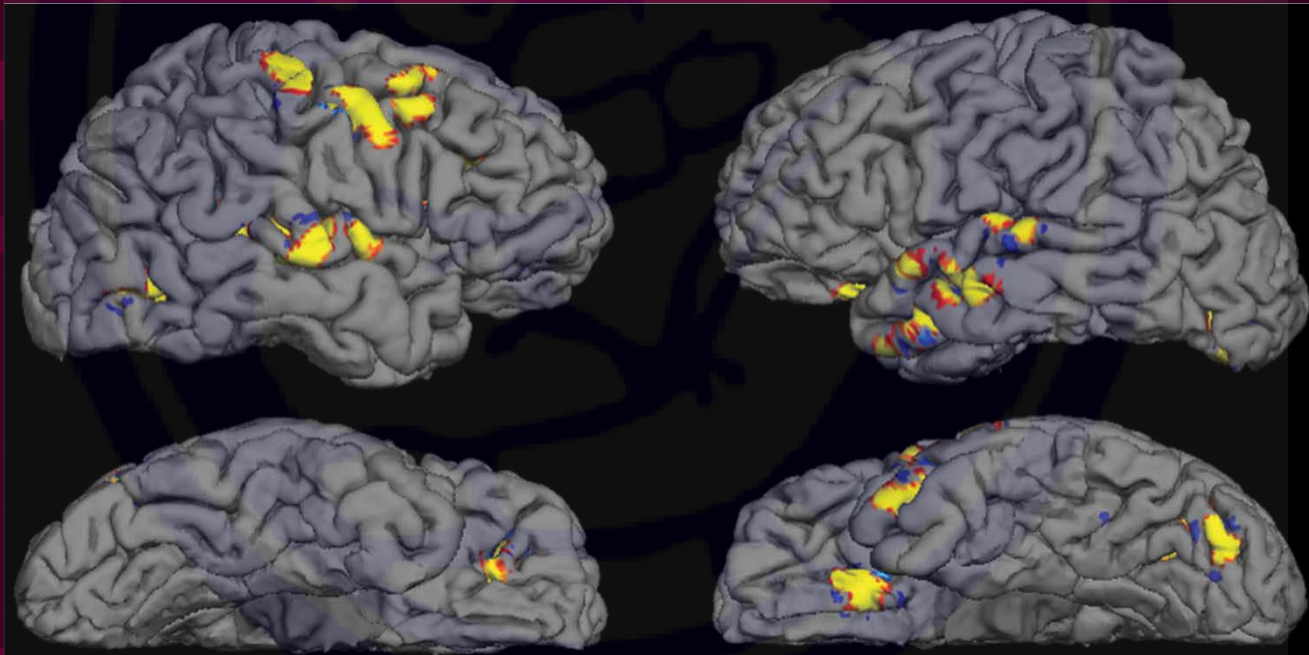
# Neurology's Transformation from a Lesional to Functional Field: fMRI and Cognition





# fMRI Studies of Music Cognition

- Localization of Music Listening v Silence
- Bilateral temporal, orbitofrontal, insular, posterior fusiform, occipital cortices



- Levitin D & Grafton S: Measuring the representational space of music with fMRI: a case study with Sting. *Neurocase* 2016

# Neuroanatomical Findings in Cognitive Neuroscience of Music

- Music activates widespread bilateral areas of the cerebrum as well as cerebellum.
- Listening and imagining music activate similar areas, which are different than imagining prose or visual art.
- Perception begins in A1 (primary auditory cortex); different neuronal clusters for pitch, timbre, duration, volume.

# Cognitive Neuroscience of Music

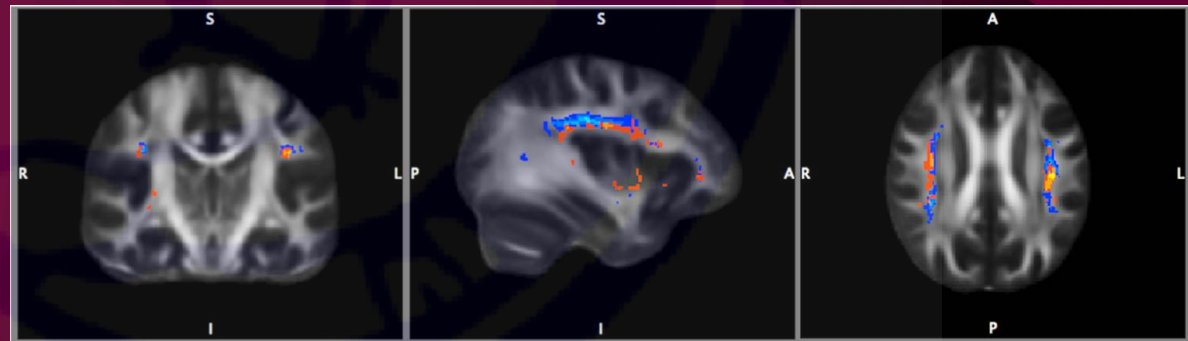
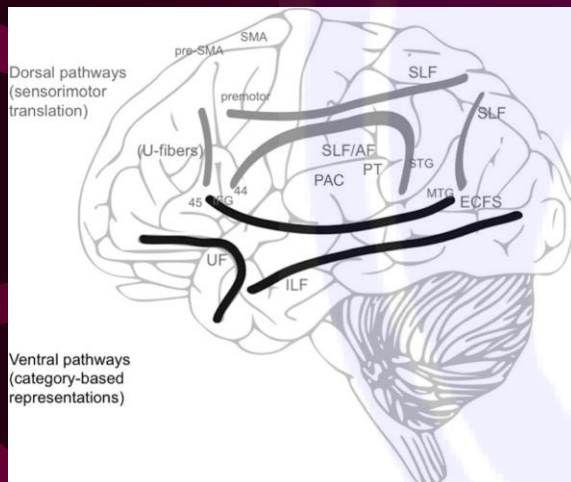
- Orbitofrontal cortex (B47) involved in expectancy generation, i.e. sequential patterns.
- Emotional reactions to music involve cerebellum, medial frontal lobes, n. accumbens, amygdala.
- Areas involved in expectations are active with no music and *deactivate* w/music.  
“Editing cortex” – relevant to improvisation...

# DTI and Music Cognition

Pitch center – Heschl's gyrus (deep, transverse to sup temporal gyrus);

DTI study – arcuate fasciculus correlates with pitch

Loui & Schlaug G 2009

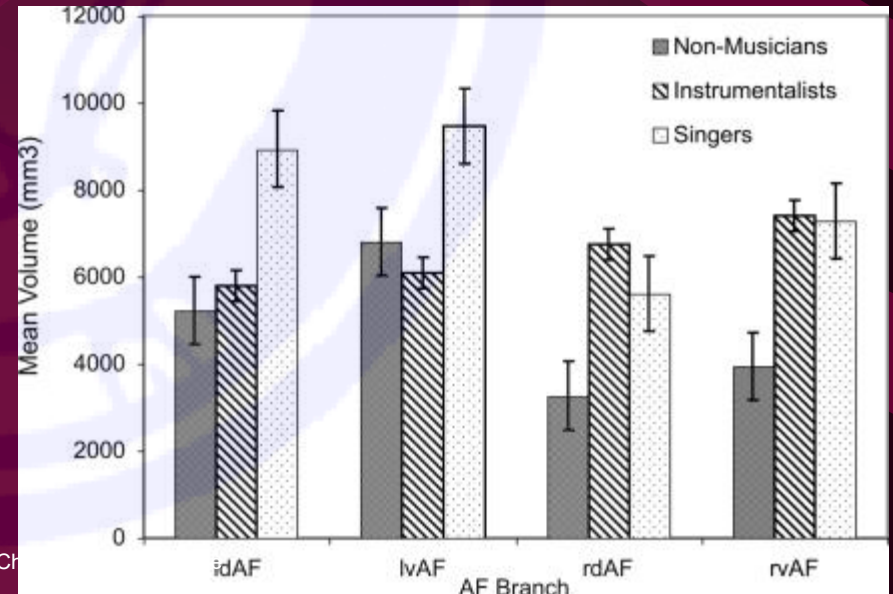


Yuskaitis, Parviz, Loui, Wan, Pearl: Neural Mechanisms Underlying Musical Pitch Perception and Clinical Applications Including Developmental Dyslexia  
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 Curr Neurol Neurosci Rep 2015



# Arcuate Fasciculus Volume Correlates with Musical Experience

- Highest in singers, maximally left hemisphere
- Halwani, Loui, Ruber, Schlaug: Front Psychol 2011



# Human Auditory Cortex (Adults)

Only finding everyone agrees on: **tonotopy**

Scan subjects while they listened to 165 real-world sounds;  
then looked for structure in the data;

Using a hypothesis-neutral method  
(variant of ICA).



Two components account for most of the variance outside A1...

# Auditory Cortex

Creativity and the Brain

Tonotopy long known but

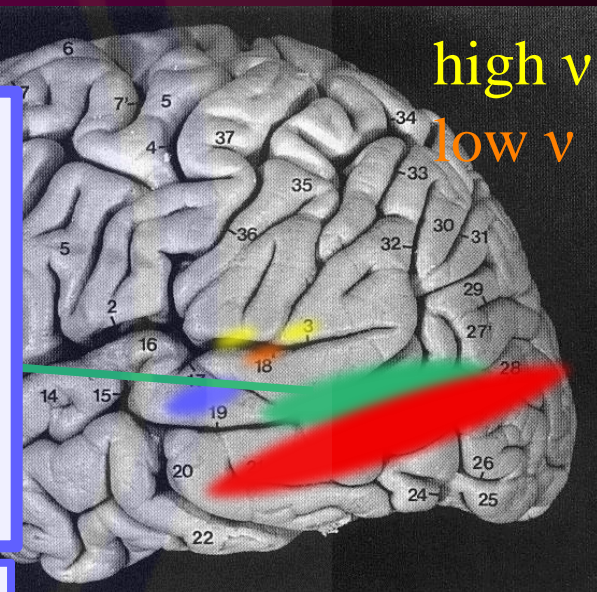
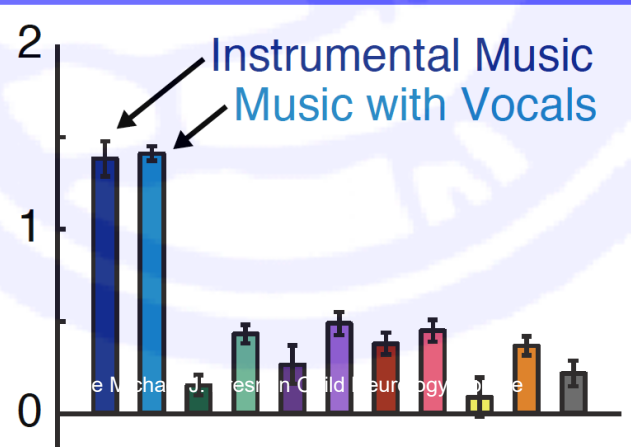
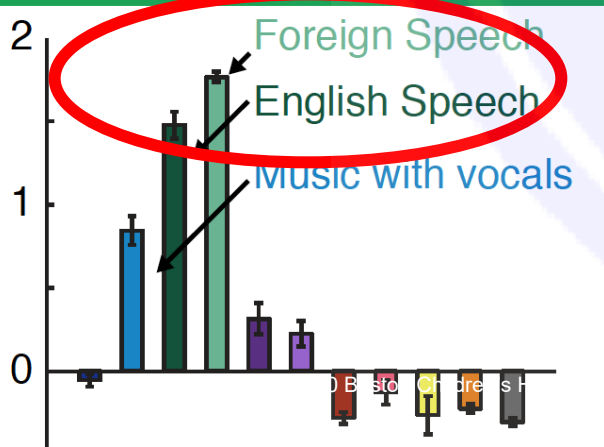
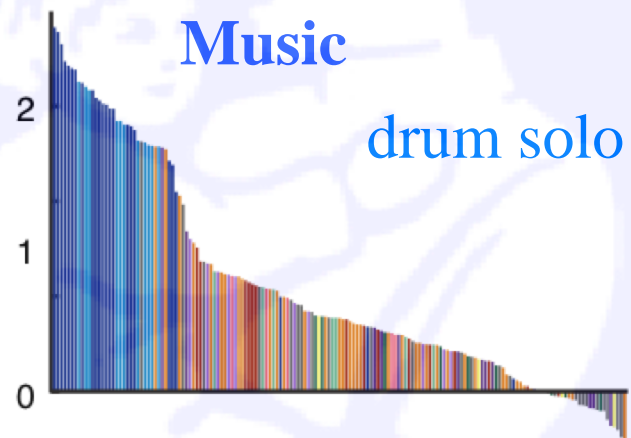
but the real surprise was...

- Instr. Music
- Vocal Music
- English Speech
- Foreign Speech
- NonSpeech Voc
- Animal Vocal
- Human NonVocal
- Animal NonVocal
- Nature
- Mechanical
- Env. Sounds

Speech



Music



Totally new, astonishing.  
For real?  
fMRI is indirect.  
Can we validate with a more  
direct neural measure?



# Auditory Cortex

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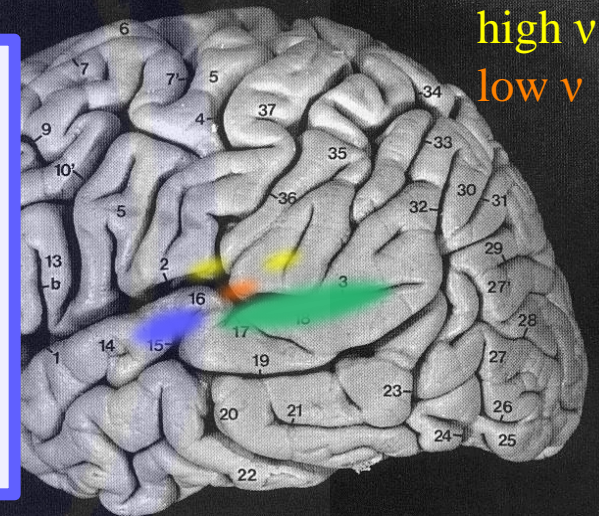
**Tonotopy** long known but  
a region specialized for **speech**  
but the real surprise is...

To find out:  
Scan infants on ~ this  
experiment.  
*Is this even possible?*

Speech



Music  
drum solo

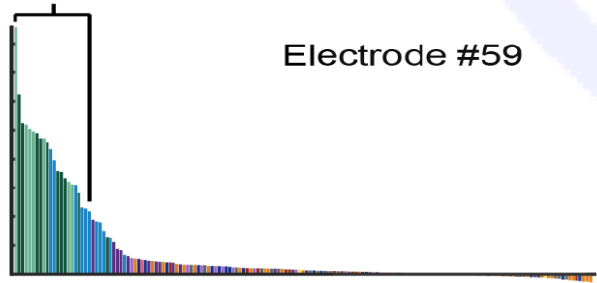


validated with intracranial recording? **Yes!**

constrains why we have music:  
not by-product of speech  
its own special mechanism  
not musicians  
basic machinery we all share  
begs the question:  
present at birth?

English Speech +  
Foreign Speech + Songs

Electrode #59

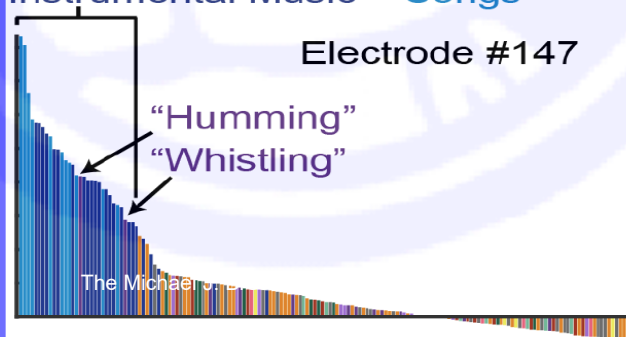


Instrumental Music + Songs

Electrode #147

"Humming"  
"Whistling"

The Michael J. Smith





# Musical Expertise – Multifactorial, Complex Phenotype, Nature/Nurture

- Pitch
- Rhythm
- Musical memory
- Instrumentalist (technique, embouchure)
- Composers
- Arrangers
- Sound
- Universal factors underlying expertise (attention, memory, will power, confidence, failures, practice)

# Cognitive Science of Improvisation

- “Overlearned” versus “Improvised”
- Overlearned = Repetitions
- Communication during Improvization

# Cognitive Theory

- Overlearned performance ~ activation of lateral prefrontal cortex
- Improvised performance ~ activation of medial prefrontal cortex

# Parcellation of Executive Functions

- Lateral prefrontal
  - Planning
  - Stepwise task implementation
  - Effortful problem solving
- Medial prefrontal
  - Meditation
  - Daydreaming
  - Complex, longterm multitasking

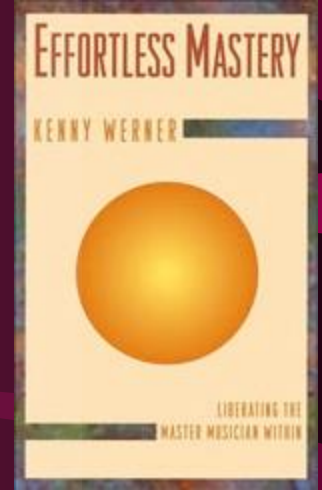


# What Characterizes Improvisation?

- Immediacy
- Involvement
- Unpredictability

# Practice makes Perfect?

- Plasticity
- 10,000 hrs of repetition – H. Simon, D. Levitin, M. Gladwell: “Perfect practice makes perfect.”
- Effortless Mastery – Kenny Werner, pianist
- Musicogenic seizures – trigger may be early childhood hymn/song, “dysfunctional plasticity,” usually R Temporal focus



# Metaplasticity – Musical training before age 9 may confer protection against musician's dystonia



Contents lists available at ScienceDirect

NeuroImage

journal homepage: [www.elsevier.com/locate/ynimg](http://www.elsevier.com/locate/ynimg)<http://www.elsevier.com/locate/ynimg>

## Structural neuroplasticity in expert pianists depends on the age of musical training onset

Lucía Vaquero<sup>a,b,\*</sup>, Karl Hartmann<sup>c,d,1,2</sup>, Pablo Ripollés<sup>a,b</sup>, Nuria Rojo<sup>a,b</sup>, Joanna Sierpowska<sup>a,b</sup>, Clément François<sup>a,b</sup>, Estela Càmarà<sup>a</sup>, Floris Tijmen van Vugt<sup>d,3</sup>, Bahram Mohammadi<sup>e,f</sup>, Amir Samii<sup>f</sup>, Thomas F. Münte<sup>e</sup>, Antoni Rodríguez-Fornells<sup>a,b,g</sup>, Eckart Altenmüller<sup>d,\*\*</sup>

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<sup>c</sup> Medical School of Hannover (MHH), Carl-Neuberg-Str., 1, 30625 Hannover, Germany

<sup>d</sup> University of Music, Drama and Media, Institute of Music Physiology and Musicians' Medicine, Emmichplatz, 1, 30175 Hannover, Germany

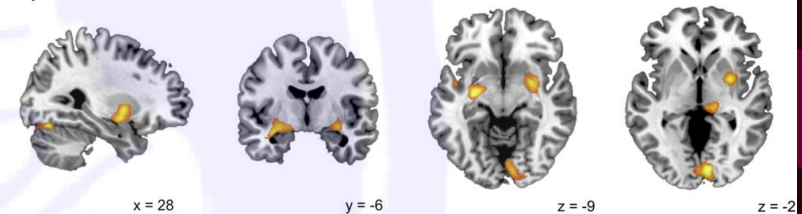
<sup>e</sup> Department of Neurology, University of Lübeck, Ratzeburger Allee, 160, 23538 Lübeck, Germany

<sup>f</sup> CNS-LAB, International Neuroscience Institute (INI), Rudolf-Pichlmayr-Str., 4, 30625 Hannover, Germany

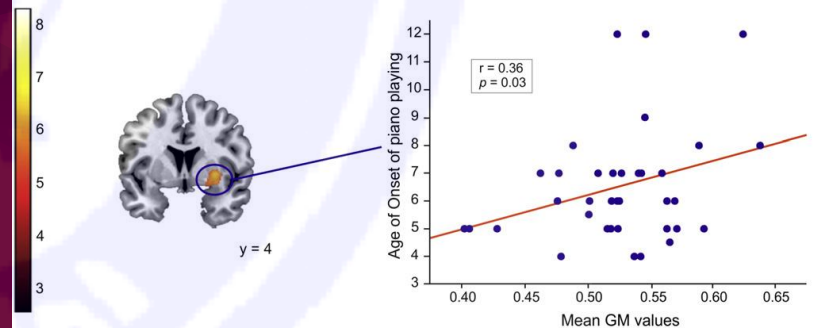
<sup>g</sup> Institut Català de Recerca i Estudis Avançats (ICREA), Pg. Lluís Companys, 23, 08010 Barcelona, Spain



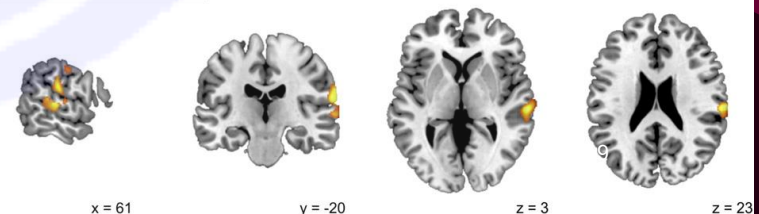
### A) Pianists > Non-musicians



### B) Right Putamen GM values correlation with Age of Onset



### C) Pianists < Non-musicians



# Metaplasticity – Musical training before age 9 may confer protection against musician's dystonia (Vaquero et al 2015)

- Pianists vs non-musicians: “reinforcement learning network”
  - ↑ bilat putamen, hippocampus, amygdala, lingual gyri; R thalamus; L sup temporal gyrus
- ↓'ed size (more efficiency?) of sensorimotor control, auditory processing, score reading
  - R supramarginal, R sup temporal, post-central gyri
- Early onset training: ↓ R putamen
  - ↑ performance (especially of L hand)



# Audio-video: Musicogenic Seizure (R temporal)

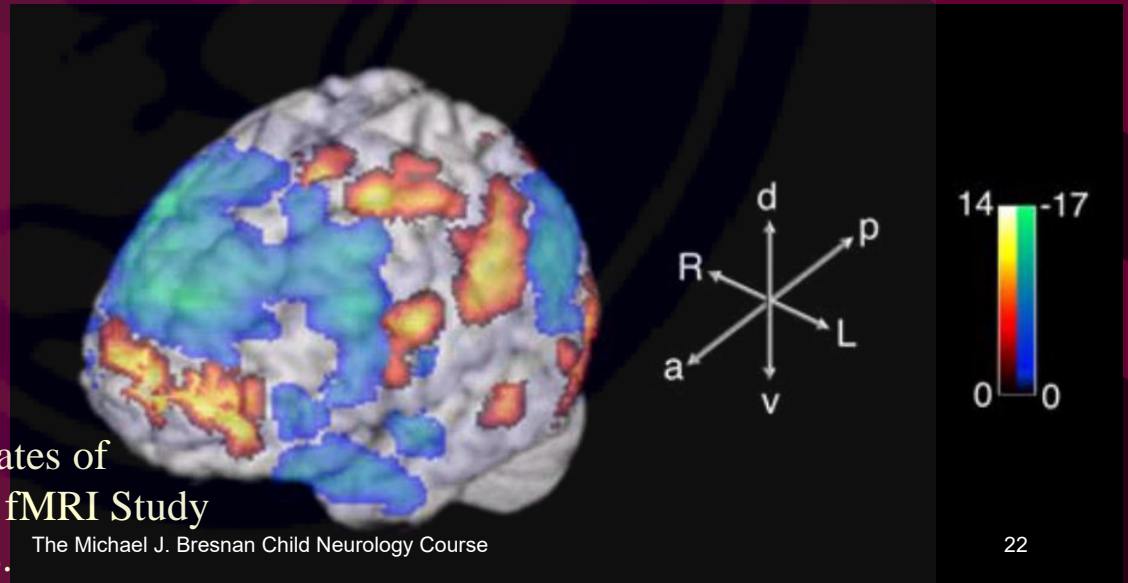
Phillip L Pearl MD

Creativity and the Brain



# fMRI Studies of Creativity

- Overlearned vs Improvised Music to same chord changes
- Medial prefrontal (frontopolar) cortex activated during self-expression
- Dorsolateral prefrontal, lateral orbital cortex *deactivated*

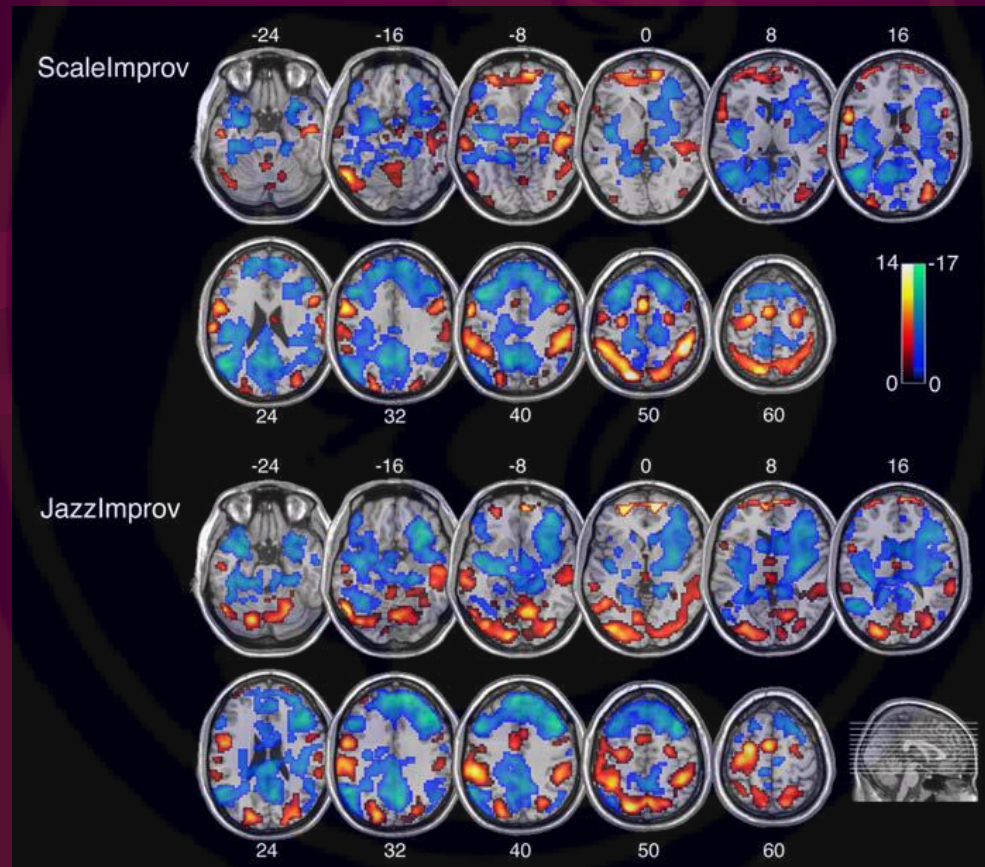


Limb CJ and Braun AR. Neural Substrates of Spontaneous Musical Performance: an fMRI Study of Jazz Improvization. PLoS One 2008.

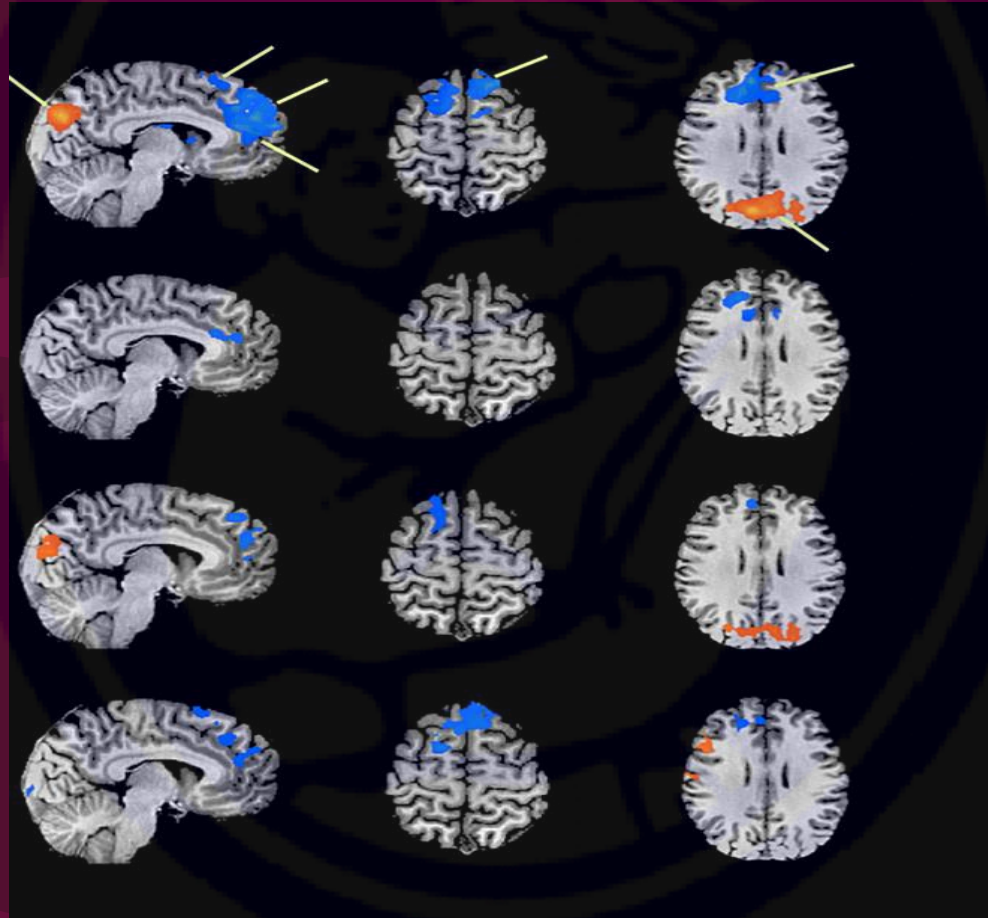
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Limb CJ and Braun AR. Neural Substrates of Spontaneous Musical Performance: an fMRI Study of Jazz Improvisation. PLoS One 2008.



# fMRI of Acting: deactivations in cortical midline network, especially dorsomedial and ventromedial prefrontal cortex



Brown et al: The neuroscience of Romeo and Juliet: an fMRI study of acting. Royal Society Open Science 2019



# Other areas affected during Improvisation

- Activation of somatosensory cortex
  - Execution
- Deactivation of limbic cortex
  - Regulation of motivation and emotion
- Trading 4's – activation of *Broca's area*

# Intersection Between Words & Music

- Scat singing
- Pioneered by Louis Armstrong
- Scat – imitative in origin
  - Def'n: use of voice to sound like a horn, e.g. trumpet or saxophone
- Summarized by Ella Fitzgerald's *Too Marvelous For Words*



Ella Fitzgerald and Joe Pass 1974

# Improvisation = complete freedom?

## A myth.

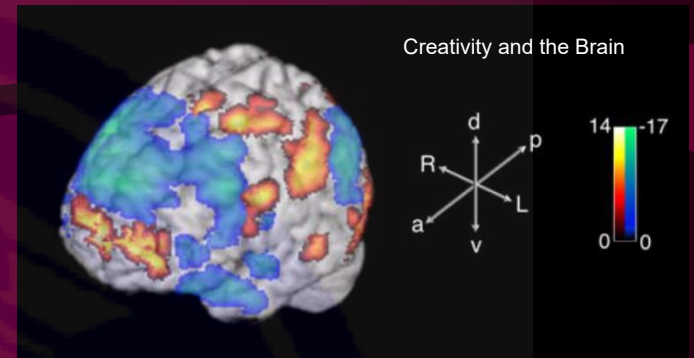
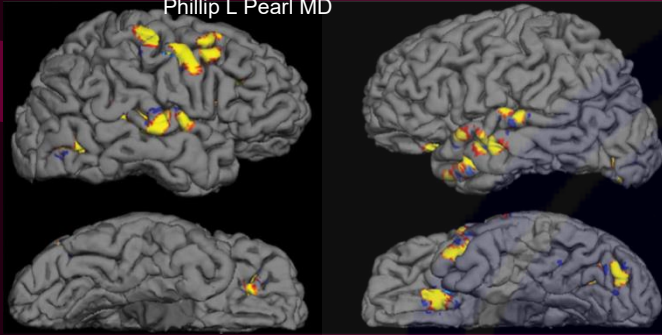
- Rules – Follow the form, rhythmically.
- Rules – Follow the form, harmonically.
- Logical chord progressions, e.g. 3-6-2-5-1.
- Logical substitutions, e.g. tritones.
- Logical voicings, even when altered, e.g. b5 on minor 7; b9, b13#9 on dominant chords.
- Playing inside the changes.
- Playing outside the changes.



# Playing along with Patients







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