Music as a window to the creating brain
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Why we study the neuroscience of music and other art forms
- Intrinsically interesting – neuroaesthetics
- Interventions
- Model behaviors for cognition in general
  - Sensory discrimination
  - Motor performance and coordination
  - Emotion
  - Social cognition
  - Executive control
  - Skill learning and expertise
  - Creativity
  - etc

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Music training and the brain

Training and expert performance

Gray matter in musicians

Krampe and Ericsson (1996), J Exp Psychol: General
Geer and Schlaug (2003), J Neuronic
**Specific gray matter effects of different musical training**

"Omega Sign" (OS) in precentral gyrus

OS-1 or OS-2

OS-2

Bangert and Schlaug (2006), Eur J Neurosci

**Musical training and gray matter – longitudinal data**

Hyde et al (2009), J Neurosci

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**Regional gray matter structure and performance**

![Graph showing gray matter volumes and performance](image)

Schneider et al (2002), Nat Neurosci

**White matter in musicians**

![Graph showing internal capsule](image)

Bangsbo et al (2005), Nat Neurosci

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**White matter in musicians**

More well-organized corpus callosum in early trained musicians

Steele et al (2013), J Neurosci

**Musical training and white matter – longitudinal data**

Hyde et al (2009), J Neurosci
Summary

- Musical training is correlated with brain anatomy
  - Gray matter (regional volume, cortical thickness)
  - White matter (organization, connectivity)
- Neuroanatomical effects are specific to type of musical training
  - Expertise-related
- Longitudinal data show differences developing over time in trainers versus non-trainers

Training effects - the problem of causality

The problem of causality 1

- Cross-sectional data
- Many causal scenarios are possible

The problem of causality 2

- Observational longitudinal studies

The problem of causality 3

- Randomized longitudinal studies
- Ideal in principle
- Practically difficult/impossible in expertise studies
  - Months/years of dedicated practice

Case in point: music training and "musical ear"

- "Musical ear" = musical auditory discrimination
- Ability to discriminate rhythms, melodies, pitches etc
- Positively related to musical training
- Musicians outperform non-musicians
- Commonly assessed in entrance exams to music colleges
Humans making music

Web-based data collection (finished Feb 2013)
- Responses from > 10,500 twin individuals
- Music training
- Musical childhood environment
- Musical auditory discrimination
- General IQ, reaction time
- Creative achievement (7 domains)
- General personality (Big Five), schizotypy
- Intrinsic and extrinsic motivation (GSM)
- Occupational preferences
- Proneness for flow experiences
- General psychological and somatic health
- Emotional processing (alexithymia)

What drives the association between training and musical ear?

- Participants
  - 1211 monozygotic ("identical") pairs (MZ)
  - 1358 dizygotic pairs (DZ)
  - 5401 single twin individuals
- Measures
  - Total hours of musical practice
  - Swedish Music Discrimination Test (SMDT)
  - Melodies
  - Rhythms
  - Pitches

Musical training and music discrimination

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<thead>
<tr>
<th>Training</th>
<th>Melody</th>
<th>Rhythm</th>
<th>Pitch</th>
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5-12% of variance in ability explained by training — other things matter!

Twin modelling

- Classical twin design
  - Compare MZ and DZ twins
- Partition phenotypic variance and covariance into:
  - A: Additive genetic effects
  - C: Shared environment
  - E: Non-shared environment

Genetic factors influence training and musical abilities

<table>
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Musical training and music discrimination ability

No significant within-pair relations for any of the music discrimination scales (r values .00 -.08)
What drives the association between training and musical ear?

Deliberate practice only explains a moderate proportion of variance in expert performance.

Practice and expert performance - metaanalyses

- Deliberate practice only explains a moderate proportion of variance in expert performance.

Multifactorial Gene-environment Interaction Model (MGIM) of expertise

- Abilities (General Q) and narrow abilities
- Personality (Conscientiousness, Openness, Agreeableness, Neuroticism)
- Interests
- Motivation
- Physical properties (Muscle strength, Height, Size of body and extremities)
- Deliberate practice

Genes $\rightarrow$ Environment

G-E covariance

Ullén, Hambrick, and Mosing (2016), Psychol Bull
Multifactorial Gene-environment Interaction Model (MGIM) of expertise

Genetic influences on musical discrimination *increase* with training

How can we get at causal effects of long-term training in expertise?

Monozygotic twins – intrapair difference model

Humans making music

Monozygotic twins discordant for piano practice

- 10 pairs with > 1300 h intrapair difference in piano practice (recruited from all over Sweden)
- “playing twin”: still active
- “non-playing twin”: no practice in adulthood
- all right-handed
Experiments

- Interviews
- Working memory tests
- Finger force control tests
- MR scanning
  - Brain anatomy (structural MRI)
    - Gray matter, diffusion MRI
  - Functional MRI
    - Sequence production, perception, improvisation

Why did the twins differ in musical engagement?

Psychological questionnaire data

- Personality
  - Playing twin higher in Openness
- Enjoying music
  - Playing twin more frequent psychological flow experiences during musical activities

Why did the twins differ in musical engagement? - Interviews

- Semi-structured interviews with five main themes
  - Own thoughts about why they became discordant
  - Childhood differences in "musical environment"
    - Music listening, music teachers, music interest of peers, parental engagement, public performing
  - Strong memories of music
  - Significance of music in your life
  - Interest and skills in language

Why did the twins differ in musical engagement? - Interviews

- Playing twin
  - More elaborate answers about meaning of music in life, emphasizing importance for personal identity
- No systematic within-pair differences in self-reported
  - Interests of peers, parental support, music teacher, ensemble playing, public performances, interest and aptitude for languages

Why did the twins differ in musical engagement? - Interviews

- Reported possible reasons for discordance idiosyncratic and unique for each pair, e.g.:
  - Different access to the piano
  - Different feelings about music genre played at home
  - Different needs for creative hobbies
  - Different feelings about the music teacher
  - Different attitudes to music as an expression of faith
  - Music-playing parent role model for one but not other twin
  - Etc
- When controlling for genes and shared environment, remaining influences are "unsystematic" in nature

Summary

- Discordant monozygotic twins provide a unique opportunity to study "pure training effects" (i.e. independent of genetic factors and common environment)
- Trained twin
  - Larger regional gray matter volume of left temporo-parietal junction
  - Higher fractional anisotropy in left pyramidal tract of playing twin
  - Higher working memory capacity for musical materials
Music as a window to the creating brain

Improvisation as a model for creative performance
- Ecologically valid
- Possible to study with brain imaging (simplified!)

What is the role of the DLPFC for improvisation?
- Dorsolateral prefrontal cortex (DLPFC)
  - Attention, working memory, selection

The DLPFC is activated when classical pianists improvise
- Improvisation (ornaments) versus from memory
  (Bengtsson et al., 2007; J Cogn Neurosci)
- Improvisation versus playing from score
  (de Manzano et al., 2012; NeuroImage)

The DLPFC is deactivated during jazz improvisation in jazz pianists
- Limb and Braun (2008), PLoS One
- Pinho et al. (2014), J Neurosci

Improvisation training and the brain
- Is specific jazz expertise one factor behind these findings?
  Does training improvisation have specific effects over and above classical piano training?
- 39 pianists (varied jazz/classical background)
- Brain activity during brief improvisations
- Associations with improvisation training (controlling for classical training)
Improvisation training negatively correlated with DLPFC activity during improvisation

Summary
- The involvement of the DLPFC in improvisation is lower for experienced improvisers
- Characteristics of the task also matter! (Pinho et al, 2015, Cereb Cortex)
  - Improvise in a given mood – low DLPFC
  - Improvise using a given pitch set – high DLPFC

Summary
- The involvement of the DLPFC in improvisation is lower for experienced improvisers
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  - Improvise using a given pitch set – high DLPFC
- Different strategies for “creative thinking”?
  - Low top-down control – high level of task-specific expertise, allow spontaneous free association
  - High top-down control – lower level of task-specific expertise, free association not useful

General summary
- Artistic behaviors and professional artists are unique models for higher human cognition
- Music and expertise
  - Expertise is multifactorial and depends on gene-environment interactions
  - Twins are useful for studies of causal effects of long-term training
- Music and creativity
  - Improvisation as a model for creative cognition
  - Prefrontal involvement in creative thinking depends on training and task characteristics

Coworkers & collaborations
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- IT, administration
  - Pelle Karlsson, Louise von Essen
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