Music Cognition Group Independent Study Project

Brown University
Spring 2014
Welcome!

At Brown, students can collaborate to develop a credit-bearing course—known as a Group Independent Study Project (GISP)—that takes on a subject outside the scope of Brown’s typical curricular offerings. Surprisingly, there is very little interdisciplinary work at Brown combining music and neuroscience, and no class addresses the intersection of these fields in a substantive way. Given our interest in this area, we teamed up to create a GISP on Music Cognition, which ran in the spring of 2014. In this packet, you’ll find an overview of the course goals and a complete description of the 12-week curriculum we developed.

If you have any questions or comments, please feel free to contact Bryn Bliska (bbliska@mit.edu) and/or Jamie Fried (jamie_fried@brown.edu). We’d love to hear from you! We’d also be happy to share with you all of the presentations developed by students in the class, which are meant to compliment the readings and foster further thought and discussion.

Best,

Bryn Bliska & Jamie Fried
Sc.B. Neuroscience ’14
Co-Coordinators

Dr. Monica Linden
Lecturer in Neuroscience
Faculty Sponsor

Jonathan Abrams, Peter Enriquez, Alex Han, Michael Karsh, Clyde Lawrence, Matthew Lee, Morgan Patrick, Ezra Rudman, Matthew Slesinski, and Marion Wellington
Participants
Course Overview

Music has been the subject of intense study throughout history. Recently, music has become the subject of a widening body of scientific research. With the rise of increasingly informative research technology, music cognition has emerged as a well-established subfield within the realm of cognitive neuroscience. Although the field of music cognition has broadened beyond the scope of a single college course, our curiosity inspired us to explore music cognition in as much depth as possible through this GISP.

The primary learning goals of this curriculum are:

1) to understand the neural processes underlying the perception, interpretation, learning, memory, creation and performance of music using an interdisciplinary approach;
2) to understand what the examination of music can uniquely contribute to the field of cognitive neuroscience; and
3) to employ this knowledge to develop and enhance our own work in the realms of musical composition and performance, sound production and design, education, scientific research, medicine and public health.

The first four weeks of the course are devoted to building a background of knowledge pertaining to the perception of rhythm, pitch, timbre and harmony. The readings include recent research on the sensory transduction, neural processing, and behavioral implications in these areas. Understanding the neural correlates of these aspects of music perception informs and facilitates the second portion of the course, which is dedicated to the study of advanced topics in the field. These include the development of musical taste, musical emotion, musical memory, music as a language, music and health, music and education, the evolution of music, and the act of creating of music.
# Weekly Curriculum

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Background: Auditory Transduction and The Physics of Sound</td>
</tr>
<tr>
<td>2</td>
<td>Rhythm</td>
</tr>
<tr>
<td>3</td>
<td>Pitch, Melody, and Timbre</td>
</tr>
<tr>
<td>4</td>
<td>Harmony</td>
</tr>
<tr>
<td>5</td>
<td>Music as Language</td>
</tr>
<tr>
<td>6</td>
<td>Musical Emotion</td>
</tr>
<tr>
<td>7</td>
<td>The Development of Musical Taste</td>
</tr>
<tr>
<td>8</td>
<td>Music, Learning, and Memory</td>
</tr>
<tr>
<td>9</td>
<td>Music and Education</td>
</tr>
<tr>
<td>10</td>
<td>Music and Health</td>
</tr>
<tr>
<td>11</td>
<td>The Evolution of Music</td>
</tr>
<tr>
<td>12</td>
<td>The Act of Creating Music</td>
</tr>
</tbody>
</table>
Week 1: Background - Auditory Transduction & the Physics of Sound

We will begin the course by establishing a common understanding of the fundamental concepts underpinning the study of music cognition. We will address the following questions:

- What are the physical properties of sound? What constitutes musical sound?
- How do the properties of waves dictate the ways sound is created and perceived?
- What tools, terms, and representative systems do we need to study and discuss sound, particularly musical sound?
- How are sounds encoded and represented in the human brain? How do the physical properties of the auditory signal transduction system shape the ways in which we perceive music?
- What techniques in cognitive neuroscience are used to study musical processing in the brain?

Presentations: “The Auditory System” and “Physics of Sound”

Readings:

  - An overview of how sound is encoded and represented in the human brain.
  - This article provides a conceptual framework for studying music as a neurobiological phenomenon, and discusses the implications of doing so.
**Week 2: Rhythm**

In examining the neural systems and processes underlying musical processing and musicality, we will begin with perhaps the most fundamental dimension of music—rhythm. We will address the following questions:

- Through what mechanisms do neurons encode time and rhythm in a musical context?
- What brain areas are responsible for perception of rhythm?
- How do musicians and non-musicians process rhythm differently?
- How are dynamic oscillations used to encode rhythm?
- How does the brain encode rhythmic expectations?

**Presentations:** “Background,” “The Neural Networks of Time,” and “The Neural Dynamics of Rhythm Perception”

**Readings:**

  - *This study uses functional neuroimaging to demonstrate that discrete neural networks are used for computing periodic and non-periodic time intervals.*
- Tierney, Adam, and Nina Kraus (2013). "The ability to move to a beat is linked to the consistency of neural responses to sound." *The Journal of Neuroscience* 33.38: 14981-14988.
  - *This study requires subjects to tap along with a steady beat and correlates accuracy of tapping with the firing of neurons in the inferior colliculus.*
  - *This study analyzes the effect of breaking rhythmic expectations on phase locked evoked gamma oscillations while perceiving a rhythm. They show that synchronous oscillations persist even when a beat is unexpectedly removed.*
  - *This EEG study demonstrates that subpopulations of neurons entrain to a pulse and subdivisions of a pulse.*
  - *This fMRI study investigates how neural activity and performance were modulated as subjects with and without musical training tapped along to progressively more complex rhythms.*
Week 3: Pitch, Melody, and Timbre

Next, we will examine the processing of pitch, timbre, and melody. We will address the following questions:

• How do we perceive pitch, timbre, and melody? Where are they processed?
• How do individuals with different cultural backgrounds and levels of musical expertise differ in their processing of pitch, timbre, and melody?

Presentations: “Pitch,” “Melody,” and “Timbre”

Readings:

  o This comprehensive paper reviews how pitch is represented in the brain at various stages of processing.
  o This study surveys the neural correlates of timbre processing using a variety of well-established techniques.
  o This text discusses melodic processing, focusing on auditory state-steady response.
  o This review discusses the neural underpinnings of absolute pitch processing and the controversies surrounding this condition.
**Week 4: Harmony**

This week, we will examine the neural basis of perceiving musical harmony, particularly the phenomena of consonance, dissonance, tension, and release. In doing so, we will discuss:

- What are the neural correlates of harmony perception?
- To what extent does our cultural background affect our perception and processing of harmony?

**Presentation:** “Harmony”

**Readings:**

  - *This comprehensive overview of neurophysiology and psychoacoustics provides background on harmony as a music-theoretical concept.*
  - *This article discusses phase locking in primary auditory cortex during perception of roughness.*
  - *This paper discusses the role of the inferior colliculus in perceiving dissonance.*
  - *This piece reviews the role of the brainstem in perceiving consonance, suggesting an opponent-process circuit of harmony perception.*
Week 5: Music as Language

This week, we will explore the following questions:

- Is there a cognitive basis for the metaphor that music is a language? How do we define “language”?
- How do music and language processing compare and contrast?
- Does musical processing of syntax and semantics provide evidence for a shared system?

Note: this week we also had a conversation via Skype with Dr. Aniruddh Patel, Assoc. Prof. of Psychology, Tufts University, who is perhaps the world’s foremost authority on music and language. We highly recommend that you contact him if you’re interested in this subject and speaking with an expert in the field.

Presentations: “Shared/Nonshared Resources,” “Semantics,” “Syntax,” and “Patel’s OPERA Hypothesis”

Readings:

  - Patel reviews current evidence on the relation of musical training to speech encoding, positing a model for cross-domain benefits, and outlining necessary future research steps.
  - Provides perspective on the syntax processing research of Patel. This article will allow us understand the experimental procedures involved in much of the ERP literature that deals with musical syntax processing.
  - Here, Patel reviews several hypotheses relating music and language representation in the brain and how they relate.
Week 6: Musical Emotion

After briefly reviewing the neural systems involved in emotion, including the mesolimbic (reward) system, we will explore the reasons we enjoy listening to music. We will also consider:

- How does music evoke a wide array of emotions?
- How do musical and linguistic emotions compare?
- What are the clinical applications of emotion evoked by music?

Presentation: “Musical Emotion”

Readings:

  - Discusses the role of the reward pathway in emotional responses to music.
  - This study found that interactions between the nucleus accumbens and auditory cortices while listening to a song accurately predict the monetary value that a subject would assign to that piece of music.
  - Investigates the relationship between pleasure states and sympathetic nervous activity in people listening to music.
  - This fMRI study finds the neural correlates of fear and joy evoked by music and examines the global modifications of attention induced by these musical emotions.
  - This article particularly considers the potential clinical applications of emotions evoked by music.
  - This study found that vocal expressions and music convey sadness using the same intervals.
Week 7: The Development of Musical Taste

This week, we will discuss:
  • Is musical taste shaped mainly by external forces or innate aesthetic preferences?
  • Why does certain music become popular?
  • How is musical taste refined over time?

Presentation: “The Development of Musical Taste”

Readings:
    o This paper reviews the neural correlates of aesthetic judgements and emotions, and ultimately posits a chronological model for the aesthetic experience of music.
    o This study found that subjects’ level of activity in the reward pathway (specifically, in the nucleus accumbens) while listening to a novel recording predicts how commercially successful that music will go on to become!
    o The study provides an alternative framework for understanding musical taste preferences beyond genre based upon five factors.
    o This study models the relationships between emotional intelligence, uses of music, personality traits, and musical preferences.
Week 8: Music, Learning, and Memory

This week, we will explore the neural basis of musical memory, the use of music as a memory-aiding tool, and cases of prodigious musical memory. We will consider:

- What are the neural mechanisms that allow us to encode musical memories?
- How does music influence brain plasticity?

Presentations: “Auditory Memory Background/Infant Memory,” “Plasticity”

Readings:

  - Compares functional plasticity in music academy students before and after two semesters of aural skills training.

  - This PET study identifies the unique brain areas underlying the retrieval of semantic and episodic auditory memories.

  - Discusses how infants learn about their auditory world, and what sounds they remember.

  - This review discusses the myriad structural and functional changes that result from musical training.

  - This study shows that adults who had 4-14 years of musical training in childhood demonstrate faster neural responses to speech sounds, even 40+ years after training.
Week 9: Music and Education

This week, we will build upon our study of musical learning and memory, considering the process of learning music from the point of view of professional musicians as well as children and students. We will address:

- How can an understanding of music cognition improve pedagogy in music education?
- What are the implications of teaching individuals music?

Presentation: “Music & Education”

Readings:

  - This article discusses how lifelong music practice correlates with increased activity in certain brain structures, cortical synchrony, and gray matter thickness.
  - This study proposes the hypothesis that the “Mozart Effect” is a product of music’s ability to reduce the unpleasantness of sustained cognitive dissonance. They support this by showing that agreeable music causes longer sustained effort and improved scores on stressful tests.
  - This longitudinal study reveals that participation in weekly 45 minute instrumental music training for 18 months performed significantly better on tests of verbal memory.
  - This chapter posits that the five skills that underlie reading acquisition all rely on auditory neural synchrony, suggesting that musical training enhances reading skills. They then review longitudinal studies that confirm this hypothesis.
**Week 10: Music and Health**

This week, we will take on the big question, “How can music impact health outcomes?”

- How do different patient groups relate to music?
- How is music therapy applied for different patient groups, and by what mechanisms do music therapies support healing in these people?

*Note: this week we also had a conversation via Skype with Dr. Nina Kraus, Assoc. Prof. of Neurobiology & Physiology at Northwestern University. She is a leading researcher in the field of music, education, and aging. We highly recommend that you get in touch with her if you’d like to speak with her directly about her work.*

**Presentation: “Music & Health”**

**Readings:**

  - *Strait and Kraus provide meta-analyses of the specific auditory enhancements that children gain as a result of musical training.*
  - *This talk gives a current example of the utility of music therapy, especially for marginalized populations as an alternative to biomedical treatments.*
  - *This paper describes a technique for enhancing melodic intonation therapy outcomes on speech fluency using transcranial direct current stimulation.*
  - *This study uses fMRI and TMS to identify the functional changes subserving music therapeutic enhancements of fine and gross motor control.*
  - *This article reviews the neurobiological evidence that suggests music can positively impact health in a number of disease states.*
Week 11: The Evolution of Music

This week, we will consider music as an evolutionary biological phenomenon. To invoke a phrase used by Stephen Pinker – is music merely “auditory cheesecake,” or does it have an evolutionary purpose? We will address:

• Why do humans and other animals have musical ability? How might it be adaptive?
• How does the evolution of music relate to the evolution of language?
• Is our preference for different types of music built primarily on cultural or evolutionary foundations?

Presentations: “Overview” and “Musilanguage Theory”

Readings:

  o Cross examines the evolution of music in the context of both biology and social interactions, suggesting that music has shaped the evolution of the human mind.
  o Brown analyzes phrase structure and phonological properties in music and language, arguing that they share a common evolutionary origin.
  o This excerpt contextualizes Pinker’s line about “auditory cheesecake” within his non-adaptationist arguments.
Week 12: The Act of Creating Music

This week, we will take a cognitive neuroscience approach to the act of musical expression in the form of improvisation/composition, as well as the experience of musical imagery.

- What are the neural substrates of musical improvisation and how do they relate to executive functions?
- What neural processes are involved in viewing/listening to a musical performance and how do they contribute to the evaluation of a performance?
- How does musical imagery arise? What are the neural substrates of musical imagery?
- How else might we imagine composing music using data from the natural world?

Presentation: “The Act of Creating Music”

Readings:

  
  o  This paper identifies and discusses the additional neural resources that are recruited when improvising.
  
  o  This case study describes a jazz guitarist who made a full recovery after undergoing a temporal lobectomy for temporal lobe epilepsy.
  
  o  This study found that video alone, rather than video with sound or sound alone, of classical pianists performing in a competition enabled expert and non-expert judges to predict the competition winner most accurately.
  
  o  A review of recent findings on musical imagery, which also discusses the practical applications of this research and methodological challenges in the field.
Additional Resources

**Week 2: Rhythm**

**Week 3: Pitch, Melody, and Timbre**

**Week 4: Harmony**

**Week 5: Music as Language**
Music Cognition: Additional Resources


**Week 6: Musical Emotion**


**Week 7: The Development of Musical Taste**


**Week 8: Music, Learning, and Memory**


**Week 9: Music and Education**


**Week 10: Music and Health**


**Week 11: The Evolution of Music**


**Week 12: The Act of Creating Music**


Ragert et al. (2013). Knowing too little or too much: the effects of familiarity with a co-performer’s part on interpersonal coordination in musical ensembles. Front Psychol. 25(4), 368.