

## ARTICLE

# Music and the Mind: A New Interdisciplinary Course on the Science of Musical Experience

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In this paper the instructors describe a new team-taught transdisciplinary seminar, "Music and Mind: The Science of Musical Experience." The instructors, with backgrounds in music and neuroscience, valued the interdisciplinary approach as a way to capture student interest and to reflect the inherent interconnectivity of neuroscience. The course covered foundational background information about the science of hearing and musical perception and about the phenomenology of musical creation and experience. This two-credit honors course, which attracted students from eleven majors, integrated experiential learning (active listening, journaling, conducting mini-experiments) with rigorous reflection and discussion of academic research. The course culminated in student-led discussions and

presentations of final projects around hot topics in the science of music, such as the 'Mozart Effect,' music and religious experience, etc. Although this course was a two-credit seminar, it could easily be expanded to a four-credit lecture or laboratory course. Student evaluations reveal that the course was successful in meeting the learning objectives, that students were intrinsically motivated to learn more about the discipline, and that the team-taught, experiential learning approach was a success.

*Key words: music perception; auditory analysis; transdisciplinary learning; embodied cognition; team-teaching*

### Why Music and the Mind?

Music is one of the great mysteries of human experience. Although it provides no obvious direct benefit to survival, all human cultures have developed music, and the brain has circuits for the analysis of music that are distinct from language processing (Polk and Kertesz, 1993). The perception of music is also a growing field within cognitive neuroscience; the Musical Brain Imaging Research Database (MusicBIRD) includes over 450 primary research articles on neuromusical research (Edwards, 2008). This research focus has captivated the public as well. The publication of two popular science books by cognitive neuroscientist and rock musician Daniel Levitin (2006, 2008), have made him the best selling scientist in the last decade. Given the widespread interest in music among students, we believed that the topic would attract students from a wide variety of majors, and would serve as an excellent springboard for discussion and critical inquiry.

We also noted that it would be rewarding to teach this class from the perspective of embodied cognition. By including exercises in experiential learning, students would be able to feel the cardiovascular changes associated with performance anxiety, monitor changes in body posture during a live performance of a Mozart sonata, and baffle at the mind's faulty interpretations of auditory illusions. The interdisciplinary nature of the course also appealed to us. It allowed us to draw from the collective wisdom of students in many different majors and to better understand one discipline through the lens of the other. Given the pedagogical emphasis on interdisciplinary learning as a core feature of a liberal arts education, and the emerging importance of integrating the humanities and social sciences into the undergraduate neuroscience curriculum (Wiertelak and Ramirez, 2008), this course seemed like a natural fit for the instructors and for motivated students

seeking a degree at a liberal arts university. We were also bolstered by the success of other transdisciplinary neuroscience courses such as Art and Vision (Lafer-Sousa and Conway, 2009) and Sex, Brain and Gender (Mead, 2009).

The course was co-taught by neuroscience instructor Roxanne Prichard and music instructor Vanessa Cornett-Murtada. Prichard teaches courses in brain and behavior, sensation and perception, and physiological psychology; and Cornett-Murtada teaches courses in piano performance and music pedagogy, and works as a performance coach for musicians suffering from performance anxiety. We met at a Midwest Faculty Seminar on Embodied Cognition at the University of Chicago and quickly learned that we share a special interest in the science of hearing and musical perception as well as the phenomenology of musical creation and experience.

### Audience

This course was offered to undergraduate students in the Aquinas Scholars Honors Program at the University of St. Thomas in St. Paul, MN. This program, designed to challenge dedicated and high-achieving students, requires students to take four interdisciplinary honors seminars as part of the graduation requirements. These two-credit seminars meet once per week for an hour and a half, are team-taught by two instructors in separate disciplines, and are designed to focus on creative and experimental topics. The class consisted of 14 Aquinas Scholars, mostly juniors and seniors, with a wide variety of majors: Business (5), Biology or Biochemistry (2), Music (2), Economics (2), Electrical Engineering (2), Computer Science (1), Catholic Studies (1), International Studies (1), Journalism (1), and Political Science (1).

Topic	Experiential Learning Activity
How is music a fundamental part of human experience?	Discussion of personal music histories, including earliest memories, formal lessons, functions of music, peak experiences
How do we define music? What is its purpose?	Performance of Cage's '4'33"; defining music from the perspectives of music, psychology, philosophy and physics disciplines
How do the ears and brain process sound? How is listening different from hearing?	Modeling the auditory pathways from the pinna to auditory association areas
Are humans innately musical beings?	Exploration of universal sound motifs and discussion of anthropological evidence of song and music performance
What can variations in responses to sound teach us about the neural processing of music?	Experience of auditory illusions including phantom words, the tritone paradox and the McGurk effect
How is memory tied to music? Why do we have 'earworms'?	Discussion of sensory, short term and long term memory encoding; quantitative comparison of earworm 'infections'; discussion of musical memories
How does music have the power to influence mood?	In-class quantification of tension during a live performance of Mozart; discussion of movie soundtracks and the film <i>Once</i>
Music and mental health: What is the link between madness and musical creativity?	Role-playing: autobiographical statements from musicians with mental illnesses; analysis of Schumann's two musical personalities
How does musical experience shape cognitive and language development?	Critical analysis of Baby Einstein and the Mozart Effect; demonstration of critical periods in language development through a lesson in Vietnamese tonality by a native speaker
How is musical expression and performance influenced by flow? By anxiety?	Unannounced music improvisation activity and drumming circle

Table 1. Examples of discussion topics and in-class activities.

## Course Design

This course was created to integrate the disciplines of music and neuroscience to explore the fundamental relationship between music and the brain. The specific goals of the course were to 1) learn the basic principles of the neural processing of sound, 2) gain a broader understanding of and appreciation for the art and science of music, and 3) integrate knowledge from both fields through active listening, reflective writing, and critical discussion. It was open to any student in the Aquinas Scholars Honors Program, regardless of major or previous coursework. Since it was designed as a seminar, the instructors most frequently acted as guides, information resources, and discussion participants rather than as lecturers. Each week, students were expected to bring questions and personal reflections to class, new articles and resources, and additional musical examples on a CD, iPod, or as an internet link. We used Blackboard for the course; the assignments tool allowed us to evaluate assignments and provide feedback together, and the discussion board was used often by the students to share musical examples with each other.

To prepare for each class meeting, students read various assigned articles, listened to specific musical examples, and answered discussion questions as part of a course journal. Each week we focused on a particular set of questions, and prepared active learning strategies to stimulate discussion (Table 1). Students were required to be actively involved in the exploration, discussion, reflection, and expansion of course topics through in-class discussions and presentations and out-of-class responses to reading and listening. The course culminated in student presentations of an interesting variety of final project topics (see Table 2). Topics were proposed by the students and approved by the instructors, and were required to show evidence of the student's ability to synthesize material from

the disciplines of music and neuroscience or related fields. Half the course grade was determined by student performance on reading and listening journals that were collected electronically each week (see supplementary materials). We evaluated students on their ability to synthesize the phenomenological experience of specific music listening assignments with the scientific principles of auditory processing. We also based our assessment on the depth of their understanding and analysis of the assigned material, and the unique reflections, real-life examples, and additional readings and musical recordings which they provided to support their answers. The other half of the course grade was based on student participation in class discussions and on the final presentation.

The primary text, Daniel Levitin's *This is Your Brain on Music: The Science of a Human Obsession*, was supplemented with several academic articles on various topics of neuroscience and music (see Course Readings list at the end of this paper). Through the readings, students were expected to integrate scholarly research with personal observations, and to synthesize information from the disciplines of music and neuroscience. Readings were taken from neuroscience, psychology, and music journals, and included perspectives from philosophers and music composers and performers.

The music listening assignments included a wide variety of examples from Western art and popular music, world music traditions, and avant-garde or experimental music. They were designed to be provocative, challenging students' perceptions of the definition of music, and opening their minds and ears to new ways of processing organized sound. We favored musical pieces that aroused specific emotional responses, that were particularly annoying, that were especially catchy or addictive, that contained universal sound motifs, or that could arguably be used to manipulate the listener (such as commercial

jingles, film scores, etc.). Students also used the journals to organize notes, answer discussion questions, record observations, or propose their own questions.

Final Projects	Neuroscience Themes Explored
Why do we tap our feet to music?	Basal ganglia; rhythm detection in language; cerebellum
Effects of prenatal music exposure	Neural development; synaptic pruning; stress hormones
Music and chant used in meditation	Altered brain states; EEG rhythms; learning and memory
Computer modeling of A1 in three species	Computational neuroscience; tonotopic mapping; plasticity
Psychedelic rock	Psychopharmacology; synaesthesia
Beethoven's mind	Genetics; bipolar disorder; deafness; stress
Musical savants	Autism Spectrum Disorder; learning and memory
Music in political advertisements	Anxiety; stress; associative learning
Does studying music make you smarter?	Intelligence; attention; learning; lateralization of function

Table 2. Examples of students' final projects. Students were required to integrate the fields of music with neuroscience to explore a theme of particular personal interest.

## Resources

In selecting musical examples, we chose a variety of familiar and unfamiliar music from both Western art ("classical") music and vernacular (rock, folk, world) music traditions. We made a conscious decision to emphasize pieces that would challenge the students and encourage them to explore and shape their own musical preferences. They listened to Beethoven symphonies, African improvised ensembles, avant-garde pieces for bowed piano, and Viking folk metal by the Danish band Svartsot. Pieces by the American composer John Cage, such as *4'33"* (which consists only of four minutes and thirty-three seconds of silence) and *Two3* (which contains a sparse number of blips and squawks separated by large spans of silence) generated a great deal of discussion about the difference between music and noise or sound, and how the brain interprets certain sounds as music and other sounds as noise.

Table 3 shows a few examples of listening assignments which were paired with neuroscience readings about particular topics. For the discussion about why certain songs get stuck in our heads as "earworms," for example, we chose simple songs with highly repetitive or addictive refrains, such as the children's song "The Wheels on the Bus," "The Merry Old Land of Oz" from *The Wizard of Oz*, the repetitive 1982 rock song "Jenny (867-5309)" from the band Tommy Tutone, and the 2008 song "So What" by current pop-rock singer P!nk. When students were asked to post audio links to their own addictive earworms on a Blackboard discussion board, they submitted an interesting variety of children's songs and nursery rhymes, advertising jingles, Broadway songs, and rock and hip-hop selections. For each song they posted, the students were required to identify the unique musical characteristics (melodic range

and contour, rhythmic motives, repetition of text, etc.) that made the piece potentially addictive to the listener as an earworm.

Although not essential to the success of the class, our use of a smart classroom in the music department provided unique opportunities for a variety of musical activities. We made full use of the grand piano, music staff board, access to percussion instruments, and an audio system with stereo speakers. The polyphonic speaker system was essential for use with the audio examples by Diana Deutsch, whose CDs of auditory illusions, *Musical Illusions and Paradoxes* and *Phantom Words and Other Curiosities*, use simultaneously competing binaural streams. Deutsch, a Professor of Psychology at the University of California, San Diego, has a research focus on perception and memory for sounds, particularly music, and has discovered a number of interesting auditory illusions. For example, Figure 1 demonstrates the Chromatic Illusion, in which listeners often hear stepwise ascending and descending scale patterns rather than the actual disjunct series of pitches generated.

Discussion questions and musical listening examples for each week were posted on Blackboard. Our university library, like most, subscribes to a variety of online streaming audio resources which students can access from on or off campus. Our particular resources, Naxos Music Library, Naxos Music Library Jazz, DRAM Online, and Smithsonian Global Sound, provided free streaming of hundreds of thousands of audio tracks of all musical styles and genres. Instructors may paste URL links or create course-related playlists within each database for student access. For musical selections not available through these resources, we provided links to public video-sharing websites such as YouTube.

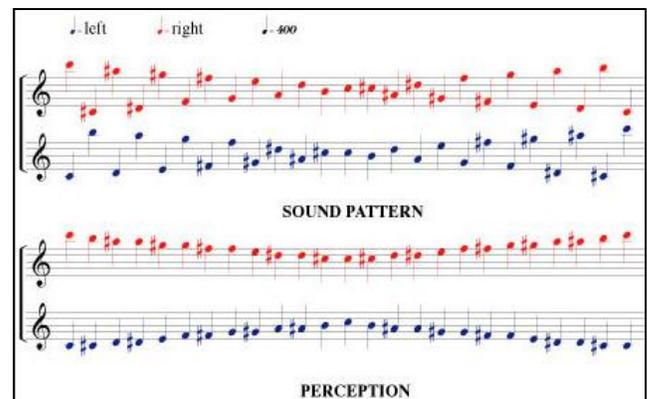


Figure 1. Deutsch's Chromatic Illusion, as the notes are actually played (above) and as they are perceived through stereo speakers (below). This and other auditory illusions are available at <http://www.philomel.com>. Used with permission.

## Pedagogical Approach

Our focus was inquiry-based learning. Towards the beginning of the course the questions to be discussed were broad and fundamental. (What is music? How and what does music communicate? How does the brain process music?) As the course progressed, students

Class Topic	Listening Assignments & Composers
Earworms	Jenny (867-5309) : Tommy Tutone The Wheels on the Bus: Traditional The Merry Old Land of Oz: Arlen/Harburg So What: P!nk
Mental illness	Carnaval, Op. 9, "Eusebius" and "Florestan" Kreisleriana Op. 16 No. 1 Davidsbündlertänze, Op. 6, Nos. 4 and 8 Fantasietücke, Op. 12 No. 1 Kinderszenen, Op. 15 No. 7 (all Schumann)
Emotional response	Symphony No. 7, II. Allegretto: Beethoven Adagio for Strings, Op. 11: Barber Ghost-Nocturne for the Druids...: Crumb Judgment Day: Galas Kromandens Datter: Svartsot
Communication	<i>Once</i> (movie soundtrack) : Hansard/Irglová D'Gary Jam: Béla Fleck
Expectation	Symphony No. 94 in G major: Haydn Two3; 4'33": Cage
Synaesthesia	Quartet for the End of Time: Messiaen Preludes Op. 74 Nos. 1 and 5: Scriabin The Struggle for Existence: Liszt Rainbows I for bowed piano: Scott
Flow	Desert Song: Nakai Salva Me: Barquee Brainwave Theta Meditation: Theta Realms
Cognition	Baby Mozart (The Baby Einstein Co.)

Table 3. Each week, students actively listened to particular musical selections, and answered questions around a particular neuroscience/psychology topic related to those pieces (see supplementary materials).

began to explore more complex problems. (Are humans innately musical beings? Why do we get certain songs stuck in our heads? Does music have the power to influence mood? How and why do people develop musical preference? What is the link between musical creativity and madness?) Each class period integrated experiential learning activities such as active listening, journaling, and conducting mini-experiments with rigorous reflection and discussion of academic research on music perception (see Table 1 for examples of in-class activities). For example, to facilitate the discussion of trance, students participated in a drumming circle using a variety of African hand drums. To demonstrate the complex relationships between music composition and mental illness, students researched and role-played a variety of well-known musicians. They provided short, often poignant, autobiographical narratives about the nature of musical genius and the mental health challenges of creative artists. Examples included Kurt Cobain (ADHD and substance abuse), Billie Holiday (PTSD and substance abuse), and Alexander Scriabin (hypochondria and bipolar disorder).

### Integration of Neuroscience Principles

The topic of musical experience was a natural fit for teaching neuroscience to non-major students. The second meeting of the class was dedicated entirely to understanding how the brain and ears translate air

pressure variations into the phenomena of music perception. To prepare for this topic, students constructed individual flow charts of what must happen in different regions of the ear and brain in order for one to perceive a particular piece of instrumental music. We had students work in three groups (outer ear to cochlea, cochlea to the primary auditory cortex, and cortical auditory association areas) to draw these flow charts on the entire length of the room's dry-erase boards. Using this student-generated illustration, we were able to introduce concepts such as sensory transduction, tonotopic organization, synaptic integration, thalamic gating, neural connectivity, localization of function, and higher order functions such as language processing and production. We then asked students what happened in their minds (what thoughts, memories, emotions and bodily responses they had) when they heard a particular piece of music, and added neural regions responsible for attention, memory, motor, mood and autonomic responses into the flow chart.

Even though our synaptic connections on the board numbered in mere dozens rather than in the actual trillions, students nonetheless left the class with a much better understanding of the brain's organization and connectivity and a sense of awe at the complexity of the brain.

Narrative comments from course evaluations indicated that this was one of the most helpful exercises of the semester. One student comments, "The day we went through and explained to the class how music reaches our brain was very helpful - the scientific articles were a little confusing."

Throughout the rest of the course we returned to these concepts and studied how different experiences (Beethoven's deafness, Schumann's bipolar disorder, Syd Barrett's schizophrenia, John Lennon's LSD use, Tori Amos' synaesthesia) would alter auditory processing. Developmental plasticity was also a major recurrent theme throughout the course as we discussed the formation of musical preferences, critical periods in phoneme distinction, and the phenomena of perfect pitch, which is significantly more common in speakers of tonal languages. Throughout this course, students also got to experience the true interdisciplinary nature of neuroscience through the diversity of experimental approaches discussed in the readings. For example, we discussed anthropological evidence of changes in cranium, vocal cord and ear structure in early hominids, psychophysical responses to particular auditory cues, neuroimaging responses to different types of music, and clinical case studies of bipolar disorder, autism spectrum disorder, depression, and substance abuse.

### Evaluation of Resources

Levitin, a rock guitarist, sound engineer, and cognitive psychologist, provides a fairly solid background in both music and neuroscience in *This is Your Brain on Music*, and infuses the text with relatable pop-culture references. Although we were occasionally irritated by some of the technical over-simplifications in both fields, the text provided the students with a foundation in basic music and auditory perception, and raised many provocative

questions for discussion. Some students struggled with primary scientific literature; however, by providing guiding questions for each reading, and opening class discussions with inquiries about what was most confusing about each article, we were able to help students work through some of the more dense material.

**Student Evaluation**

The University of St. Thomas uses the IDEA Center teaching evaluation form ([www.theideacenter.org](http://www.theideacenter.org)), which measures student self-rated progress towards specific learning goals. These ratings are then compared at the departmental, university, and national level. Overall, students evaluated the course very highly (Table 4). Ten of the fourteen students said they would “definitely” recommend it to a friend; of the three who were “not sure” and the one who said “definitely not,” all indicated that the major reason for not recommending it was that they thought it was too challenging and/or time consuming. Students in particular benefitted from the inquiry-based discussions and experiential learning. When asked what elements of the course were most effective for learning, more than half of the students indicated that they learned the most from the active listening exercises. Student feedback also indicated an appreciation for the encouragement to pursue their own questions, and for the level of analysis which tended to “focus on open-ended questions” and “encourage deeper thinking.” Four students indicated that the final projects were the educational highlights of the course. The students also evaluated the in-class interactive activities such as the drumming circle, musical improvisation activity, and mini-experiments in auditory perception as successful learning tools.

Students’ Quantitative Course Evaluations	Rating
E: I gained a broader understanding and appreciation of intellectual/cultural activity.	4.3 (0.7)
E: I acquired an interest in learning more by asking questions and seeking answers.	3.9 (1.0)
I: I learned fundamental principles and theories.	3.9 (0.8)
I: I learned to analyze and critically evaluate ideas, arguments and points of view.	3.2 (0.8)
I would recommend this course to a friend.	4.3 (1.2)
I have more positive feelings toward this field as a result of taking this class.	3.9 (1.0)
Overall, I rate this course as excellent.	4.1 (0.9)

*Table 4.* Quantitative feedback from student evaluations on the IDEA Center Form (n = 14). The four instructor-rated essential and important goals are denoted with an E and I, respectively. Scores range from 1 (lowest) to 5 (highest); mean ratings and standard deviations are shown.

Students also appreciated the variety of music, most of which they had never listened to before. One student observed, “the listening exercises opened me up to new ideas and types of music.” Although as one student remarked, “some of music pieces were very disturbing,” the variety of music, and the chance for students to contribute their own musical selections through blog posts kept the

students engaged and the discussions lively. The students also valued the active listening component of the journals. For each music selection, students were asked to answer specific questions about the form or structure, timbre, emotional or memory associations, etc. Writes another student, “The listening exercises were very effective at opening my mind to different music types, and really allowed me to pause and analyze my own music processing in great[er] depth.”

The course was also successful at engaging a broad range of students. We found that students’ passion for and interest in music motivated them to delve into a topic they might not otherwise have taken. None of the students were psychology or neuroscience majors, so this was brand new material for the majority of the students. Writes one student, “Very interesting topic and accessible to students from a variety of disciplines.” Other students remarked that the course was “applicable to most college students even if they have a completely unrelated to major” and included “very interesting topics... I especially enjoyed talking about things (and learning!) that I wouldn’t be able to otherwise.”

**Adaptations and Future Iterations**

This two-credit course could easily be expanded to a four-credit lecture course by simply exploring the topics listed in greater detail and incorporating more didactic learning exercises into the curriculum. In fact, the primary student critique of the course was that it covered too much information for just a two-credit seminar. This material could also easily be adapted to a laboratory course to fit almost any budget. Many sources are available online for free educational use. For example, students could explore the anatomy of the auditory system by using online animations of the ear and atlases such as the Allen Brain Atlas to visualize the structures in three dimensions and trace excitatory and inhibitory networks through functional gene expression analysis. They could experience auditory illusions such as the masking effect, tritone paradox, glissando illusion, and octave illusion, and could synthesize their own digital music through programs including a virtual keyboard. With standard neuroscience laboratory equipment, students could assay salivary cortisol during anxiety-provoking performances, perform electrophysiological recording of the frog central auditory processing system (Ferragamo and Wotton, 2006), or record EEG responses to different types of music (trance, metal, meditative, etc). Resources such as musical instruments could easily have been borrowed, substituted, or used on occasion through campus field trips.

Since all of the participants were honors students, we found the class as a whole to be an enthusiastic and dynamic group. Most students were highly motivated, interested in the subject matter, and eager to explore a variety of related topics outside of class. As a whole, class discussions were exceptionally lively, answers to the written assignments were thoughtful and thorough, and final projects were creative and interesting. For a different audience, the course might need to have more of a prescribed structure.

## Closing Thoughts

Participating in an interdisciplinary team-taught course was an especially rewarding experience. We alternated lecturing on neuroscience and music topics, were able to answer student questions from both of these perspectives, and absorbed a great deal of new information about the other discipline. Another (perhaps inevitable) benefit of team-teaching is that it led to a new research collaboration. Although designing a new course is always time-consuming, we were able to share the responsibilities of developing the course, grading assignments, and leading class discussions and activities. The course has been re-approved for the next academic year, and we look forward to our future collaboration.

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