2014

Brain Stew: Neuroscience in Beginning Instrumental Music Education

Stephen Bott
Stephen.Bott@Colorado.EDU

Brain Stew:
Neuroscience in Beginning Instrumental Music Education

a State of the Research Project by:

Stephen Bott

in partial fulfillment of

MUSC 5708
Dr. Laurie Sampsel
December 7, 2014

Introduction

Neuroscience has implications for best-practice approaches to teaching beginning instrumental music. The resources compiled here will be of immense value to the music educators who strive to bring the best out of their students. Memorizing music, developing muscle memory and coordination, and improving aural skills are some examples. This literature review will focus on research with applications for typical beginning school band students (5^{th}-7^{th} grade), and does not address issues of music and the brain with regard to infants and pre-natal brain development, senior citizens, or music therapy patients. I will also exclude studies of the "Mozart Effect" in its various guises and permutations, which is confined to listening to music, and its supposed mental enhancements for completing non-musical tasks.

The focus here is on neuroscience-based educational *methods*; evidence of brains *developing* through music practice has been proven, and successfully used to advocate for school music programs, but will be included here only as it relates to the ongoing approach to teaching that child music. Articles which focus on speech coding, tonal languages, SAT math scores, etc. will be excluded. Materials written for the primary purpose of supporting music education advocacy, and that present no original research, will be excluded. Book reviews, biographies, interviews, and bibliographies will not be included. The distinction is not always clear, but research intended only to further the academic and scientific study of the human brain, and which has no immediately relevant applications in the field of music education, will not be included.

The bulk of the literature will be relatively recent; in the field of neuroscience, material from the previous century has largely been either overturned, clarified, or supplemented, and will be included here only if it still contributes a unique perspective to the whole of the bibliography.

Critical Overview of Research Material

Sources within the general area at the intersection of instrumental music education and neuroscience run the gamut: dense, hyper-specific research on the brain, far removed from any remotely practical application, all the way to music education buzzword fluff, completely devoid of meaningful content. The best writers understand their audience, and aim accordingly. Music and neuroscience are independently complex topics, and become more so when intertwined. Music teachers are not (necessarily) neuroscientists. Even those who comprehend the entirety of any one article may lack the background to truly assimilate the material into their daily practice. Likewise, neuroscientists tend not to be music teachers, and their work may not adequately address the abilities, needs, and concerns of working educators and their students.

Key contributors to this field, unsurprisingly, tend to be intellectually curious musicians who developed an aptitude for neuroscience. Daniel Levitin immediately comes to the forefront of this category, with his 2006 New York Times bestseller and staple of the field, *This is Your Brain on Music: The Science of a Human Obsession.* Though not writing for music educators, he represents the archetype smart musician turned neuroscientist. This lends his book a sense of flow that can come only from intimate familiarity with both subjects. We need people willing and able to do the preliminary hard science for its own sake, but just as vital in the chain of communication from the spheres of science to the dialogues of music education are the people, like Daniel Levitin, with the skills to bridge that gap for the rest of us. The entire book provides numerous and compelling answers to the question posited by the introductory chapter title, “I Love Music and I Love Science — Why Would I Want to Mix the Two?” Among topics discussed are music perception, expectations and resolutions, emotion in music, and individual musicality. *This is Your Brain on Music* may still reign as the one “must-read” of the field.

The best sources deconstruct one component of music making, analyze it in terms of the brain, develop or test ideas for improving its education, and reconstruct that concept in a scientifically and pedagogically satisfying way. Ella Fourie's work on piano sightreading is an excellent example. She is specific enough for teachers to reap immediate and tangible benefits from her work, but her work is broad ranging enough that a musician with no particular interest in either sightreading pedagogy or the piano can glean something more aligned with their own discipline from the neuroscience research she presents. One key to the ongoing success of the music and neuroscience partnership is an open mind as to the outer limits of a new discovery's application. The people at work here find themselves very frequently in uncharted territory. The particular problem Fourie encounters can be summed up as follows: “Interestingly, it was found by Sergent *et al.* (1992:106) that, when tested in isolation, score reading and key pressing activated different areas of the brain, but that the specific areas associated with sight-reading as a complete process were not activated by either of these components.”[1]

Neuroscience is, arguably, *the* advantage we have over the previous generation of pedagogues. Researchers use this resource to rework conventional thinking on music curricula or pedagogy, a la Sally Chappell in her fantastic “Developing the Complete Pianist: A Study of the Importance of a Whole-brain Approach to Piano Teaching.” She presents clear scientific evidence in favor of change. Piano pedagogy is in danger of becoming entrenched as gospel; it is this breed of research that proves one would be staunchly defending the wrong side of history by

1 Ella Fourie. "The Processing of Music Notation: Some Implications for Piano Sight-Reading." *Journal Of The Musical Arts In Africa* 1, no. 1 (2004): 1-23.

trying to impede the progress of Chappell and her contemporaries. Her main point in this article is the inclusion of a more holistic scope of musicianship early in a pianist's development:

> It seems that fully developed musicians learn to process music in a combination of ways, using analytical and/or holistic approaches as appropriate. As a result of this combination of skills, it is possible that strong neural pathways are build within and between the two hemispheres allowing the brain to become increasingly efficient.[2]

Most music teachers may agree with that notion when asked directly, yet fail to put what they believe into practice. "Developing the Complete Pianist: A Study of the Importance of a Whole-brain Approach to Piano Teaching" offers the facts we need to move beyond philosophy of education and into practice.

Resources for Educators

There is no shortage of writers who distill the most salient and promising concepts in neuroscience for a band director audience (often via band director-specific publications). Diane Persillen and John Flohr, both of whom have also submitted original research, lead the pack in this category with “Applying Brain Research to Classroom Strategies.” Similar articles that fall short tend to water down the facts past the point of being useful.

The most problematic sources overall also belong to this category. They are those that present nothing original, and only rehash the established best practices in a vague or insipid way. Such articles serve only to introduce the reader to further possibilities. Of course, limited exposure to the least exciting elements of a field of study is surely better than no exposure at all.

However, the rate of neuroscience innovations is rapid. Passing off an article that does

2 Sally Chappell. "Developing the Complete Pianist: A Study of the Importance of a Whole-brain Approach to Piano Teaching." *British Journal Of Music Education* 16, no. 3 (November 1999): 253-262.

not break new ground, or even attempt to present a fresh angle on old research, is just lazy scholarship. Suzanne Schons takes this unfortunate tack in "What's Going on in There? How Students Learn." While there is nothing detrimental or antagonistic presented here, the error is one of omission. Judging from other sources in the bibliography, such as the excellent research of Herholz et al. with "Neural Basis of Music Imagery and the Effect of Musical Expertise," our knowledge of the musical brain, circa 2008 (the year of both publications), far surpassed what Schons deemed worthy of discussion.

Other articles written in the same vein manage to justify their existence by synthesizing ideas in a novel way. This works well, because so many scientific journals present papers pointillistically, with no attempt to draw a compelling narrative from newfound facts to the realities of daily life. When an experienced and thoughtful music scholar happen upon this wealth of information and chooses to create something cohesive by drawing upon their own background, we gain a digestible and helpful addition to the literature. One standout is "Brain Rules for Rehearsal," by Joseph Allison and Erin Wehr. They discuss cognitive details that are not currently in vogue in the world of education. This open dialogue, with concepts reflected upon in a novel, research-backed context, aids greatly in paving the way for further study. In this case, it is molecular biologist John Medina's twelve brain rules that are being dusted off and placed once again under the proverbial microscope.

Discovering Practical Applications

Much of the feasibility of these articles finding a welcome audience lies in aligning the facts of science with the fickle trends and federal mandates of public K-12 education. Bennett

Reimer achieves this balance in “New Brain Research on Emotion and Feeling: Dramatic Implications for Music Education.” His drama comes from opposing one of the most idolized (and most frequently misappropriated) figures in education: Howard Gardner, peddler of an as-of-yet unproven multiple-intelligences theory since 1983. Part of the thrill of attempting to reconcile music teaching with science is the “moving target” nature of both. Each new discovery can confirm, oppose, or supplement what we thought we knew yesterday. Educational practices are never implemented in a vacuum. Students lives are inevitably and irreversibly effected by the style of their schooling, and we owe them the best of our abilities. Scholars like Reimer directly enable a higher level of teaching and learning.

Jessica Grahn and Dirk Schuit have a fresh take on an age-old necessity of education: exploring, and accounting for, the strengths and weaknesses of individual students. Through their research, they have found concrete factors which show us why students' abilities to internalize and produce a beat vary as widely as they do. This type of research is valuable because it proves and explains what most of us already felt to be true, but lacked a meaningful avenue for articulating. Educational practices are, by virtue of modern legislative necessity, built on a foundation of hard data. Music teachers, along with many other “arts and activities” teachers, may feel that their lesson plans are constrained by the required amount of student assessment. The more insights like Grahn and Schuit's we have access to, the more often it is that educators can turn the challenge of arts assessment into learning opportunities that can be tailored to benefit each individual student.

Sarah Allen strikes a sweet spot of innovation and accessibility. She is able to nudge us in the direction of more enlightened music pedagogy, based on her research, which came about at the height of the recent differentiated learning styles craze. One area in which a teacher of any subject has to strike a balance is in the amount, type, and delivery style of feedback. Allen guides us on this in "Beyond Learning Styles," stating that "too much feedback" occurs at the point when students shut off the self-assessing part of their own brains, doing so because they have come to completely rely on external criticisms and solutions after every repetition of a musical passage. This is a complex set of cognitive functions, not restricted to any one area of the brain, and straddling the line between art and science. Well-executed research in this vein is crucial; Allen and her colleagues keep music teachers' best intentions in line with neuroscience-based best practices.

"This, Truly, is the Greatest Mystery of All"[3]

Fortunately, there are plenty of researchers and writers eager to work at the cutting edge. Joyce Chen is a stellar example. Her work deals with auditory processing in the brain and muscle memory. Every working musician (arguably) needs an informed stance on this. Muscle memory has its strengths and weaknesses, and a thorough understanding allows us to use that particular tool with discretion. "Learning to Play a Melody: An fMRI Study Examining the Formation of Auditory-Motor Associations" shows us how the brains of the most experienced musicians work. The short answer is efficiency, which requires that some tasks be delegated to different areas of the brain (motor-based to auditory-based processing). This transition to "auto-pilot" motor processing, in turn, requires some drill exercises on the front end of learning an instrument or technique. Chen states, "At debriefing, all participants reported using a strategy whereby they

3 V.S. Ramachandran, *The Tell-Tale Brain: A Neuroscientist's Quest for What Makes Us Human.* New York City: W.W. Norton & Company, 2010.

coded the pitches in relative terms, that is, they would compare adjacent pitches, decide if the second was higher or lower in frequency, and then relate this to their finger position.”[4] Understanding this crucial “order of operations” can help a music teacher dodge inaccurate diagnoses of musical execution issues. The people reading this research buy into the systems of practicing smarter, not harder. We would all do well to remember that mind and body act as one, and sometimes “mindless” drill is anything but mindless.

David Sternbach challenges the pedagogical conventions of music even more aggressively. Working in a more abstract and cerebral area of music with aural skills development, he presents ample evidence for its inclusion straight from the outset of a beginner's musical training. His article, "Ear Training Can Enhance Consistency and Reduce Repetitive Overuse Injuries," still feels forward-thinking, five years after its publication. Like many innovative approaches to old problems, what appears to be one solution to one issue often has unexpected, positive repercussions elsewhere. When Sternbach set out to prevent muscle overuse injuries, he realized that mental and aural practicing away from an instrument also decreases “crossed wires” in the brain while it encodes the notes from that particular practice session. These insights we value so much are made possible by the neuroscientific study of music education. Sternbach's usage of the neuroscience he discovered is simple and direct, with clear, practical, and almost irrefutable conclusions.

Stewart and Williamson contribute to the literature by recognizing that musical ability is expressed many different ways. The majority of this literature addresses either measurable music performances, or measurable (with the aid of fMRI technology) music learning. When tackling

4 Joyce L Chen, Charlotte Rae, and Kate E. Watkins. "Learning to Play a Melody: An fMRI Study Examining the Formation of Auditory-Motor Associations." *Neuroimage* 59, no. 2 (January 16, 2012): 1200-1208.

the question in an article of the same title, "What are the Implications of Neuroscience for Musical Education?," they highlight some oft-ignored areas of musical cognition: most significantly, the ability to interpret and appreciate music in complex ways, independent of a person's musical performance or composition abilities. The authors' examination of a musician's mental relationship to notation also sheds light on an under-represented area of study, especially considering how heavily most school music programs rely on notation. Consider this:

> The intuitions of performing musicians are that the melodic and rhythmic information contained within single notes are processed simultaneously, while the findings suggest that they depend on different specializations within the brain. This is true of our visual perception of the world in general: our experience is unified, even though the brain has to combine information processed from different functionally specialized areas.[5]

Findings that confirm our hunches are useful in validating educational methods. Those that overturn our suspicions allow for progress that cannot be made any other way.

Some articles may leave the reader with an overwhelming sense of, “That's great... what's the point of all this, again?” So it goes with Karin Petrini's "Action Expertise Reduces Brain Activity for Audiovisual Matching Actions: An fMRI Study with Expert Drummers." While fascinating, the only practical use of their research for a music teacher is as one additional motivation to encourage practice time. Still, we must be grateful for the scientists who are not unduly fixated on the immediate and down to earth. Someone needs to lay the groundwork for our musical, neuroscientific future. A healthy sense of perspective in recommended when tackling the most abstract concepts at the forefront of modern research in any field.

Commentary on Current State of Research

5 Lauren Stewart and Aaron Williamon. "What are the Implications of Neuroscience for Musical Education?." *Educational Research* 50, no. 2 (June 2008): 177-186.

The human brain is widely agreed to be the most complex structure, to our knowledge, in the universe. There are scientists working tirelessly to fill in the gaps in our understanding of cognition. Our technology for studying the brain is providing us with an increasing level of detail, resolution, and accuracy. Music, as a catalytic subject for brain study, is far from exhausted, and controversy over some seemingly basic tenets is far from settled. Steven Pinker, in his book *How the Mind Works,* claims that all music is “auditory cheesecake,” drawing an analogy to humanity's now far less useful predisposition for fatty and sugary foods. On the other hand, we have Daniel Levitin, author of *This is Your Brain on Music: The Science of a Human Obsession.* In a 2012 TED Talk, Levitin shows us six songs that correspond to six likely evolutionary explanations for our species's fascination with organized sound.

Thus far, we have revealed those components of the brain which play a prominent musical role. We have some idea as to how the brain grows and develops with musical training. We know, from studies of individuals with partial head trauma, that certain aspects of musical understanding can, and do, exist somewhat independently from others. Brain mapping learning (a long-term process) presents a more complex situation than mapping a discrete occurrence, such as one musical performance or one listening session. Even so, in the 21st century we have produced a solid foundation for applying neuroscience to educational methods.

Suggestions for Further Research

Naturally, there are still broad swatches of our understanding of cognition left uncharted, for a variety of reasons (technical limitations, ethical concerns, and, on the slipperiest topics, such as the root of consciousness, an uncertainty as to where, or even how, to begin). As these gaps are filled in, musician-neuroscientists will have more refined questions to ask. I suspect some effort will be put towards identifying and quantifying the subjective sides of music, those being issues of groove, feel, emotion, etc. Musical tasks can be differentiated further than they have been to date. Attentive musicians know that a staggering number of factors effect any one performance. For example, how does an experienced musician's brain handle the additional stress of performing on a secondary instrument? What “clicks” in a student's brain when they transition from playing a notated blues scale to hearing a pitch in their mind's ear, then consciously choosing to produce it? How does the auditory processing portion of the cortex refine itself, and collaborate with the motor cortex to improve intonation to the point of adjustment on the magnitude of 1/100ths of a second? There are still many low hanging fruits, so to speak, in music cognition research.

As education legislation shifts with political tides, so too will the emphasis of funded research. The current trajectory leads me to believe that as we peel away layers of cognition, the arts will be found to impact us in ever more subtle and profound ways, some barely tenable with the current state of our understanding, but always strongly suspected by music educators. Ideally, the forthcoming more defined sense of the details will allow us to discuss music education holistically, more in tune with how people develop and grow (from macro to micro and back, on a spiral, with building blocks, or whatever one's preferred analogy). Key will be maintaining a sense of proportion and scale; new discoveries, however exciting, never tell the whole story.

Implications and Closing Remarks

Today's public K-12 school climate is one of teachers justifying, with their job and pay scale on the line, every major educational decision they make. Betting on the current buzzwords within the district and trendiest research seems the safest option. However, time after time, science has played catch up on order to validate the "gut feeling" espoused by the most highly regarded figures in a field. Innovations at the grassroots, classroom level must be paired with top-down data from neuroscientists, if we are truly pursuing this branch of knowledge for the benefit of music students.

Any substitute director will tell you: rehearsal quality has at least as much to do with the band room atmosphere, generated initially by the director, as it does with the efficiency of the students' chosen mental processing techniques. When we state what the brain does, we must not lose sight of the fact that this is never abstract science; we are talking about what *people* experience, produce, and feel. People are more than the sum of their measurable cognitive functions and grey-to-white matter ratios. As in the old "Human Element" campaign of The Dow Chemical Company ads, musicians, educators, and scientists should strive to "Combine the power of science and technology to passionately innovate what is essential to human progress."

Bibliography

Section one of the bibliography consists of literature which contributes original scientific findings. Section two consists of literature primarily related to educational applications.

I.

Bartlett, Dale L., and Donald A. Hodges. "The Effects of a Music Learning Experience on a Dichotic Listening Task." *Texas Music Education Research* (1990): 9-15.

Builds on previous research, looking to clarify issues of brain hemisphere and

accuracy of musical recognition. Only conclusion of interest to the music educator is that more highly trained musicians are able to utilize more of their analytic, left hemisphere for musical purposes (contrary to the over-simplified, right brain vs. left brain). Study is outdated, admittedly a pilot, with no control group and imperfect testing methods. Still, proves that we have done away with flawed models of the brain twenty-five years ago.

Cameron, Daniel J., Lauren Stewart, Marcus T. Pearce, Manon Grube, and Neil G. Muggleton. "Modulation of Motor Excitability by Metricality of Tone Sequences." *Psychomusicology: Music, Mind & Brain* 22, no. 2 (December 2012): 122-128.

While only sampling four participants, Cameron proves that music with a strong, predictable metric pulse is much easier to literally feel. This is something to keep in mind for band directors programming more esoteric pieces, especially with younger and less experienced musicians. The process of finding the beat is mentally more complex than it may seem, activating multiple areas of the brain, and tends to happen “automatically,” or, at least, without much conscious effort or control. Each of the four participants performed differently. While a truly arhythmic person is rare, ability to identify a pulse is widely variable. Not an immediately beneficial read, but the main point is compelling.

Chen, Joyce L., Charlotte Rae, and Kate E. Watkins. "Learning to Play a Melody: An fMRI Study Examining the Formation of Auditory-Motor Associations." *Neuroimage* 59, no. 2 (January 16, 2012): 1200-1208.

Shows that people who best perform a learned melody transition most completely from motor-based to auditory based-processing. Reinforcing motor-based learning early in the process is necessary, but more accurate musicians develop efficient neural circuits, so as not to use as much brain power in this area during performances. Muscle memory, as we know, is unreliable as a primary source in a stressful performance. Chen is well-versed in both neuroscience and motor skills. Article is a written for the scientific community, and not deliberately aimed at educators, though a thoughtful music teacher can inform their curriculum, armed with this knowledge. Particularly useful for those teaching the first years of instrumental music, a time that is easy to belabor the point of motion at the cost of the actual musical sounds being produced.

Fourie, Ella. "The Processing of Music Notation: Some Implications for Piano Sight-Reading." *Journal Of The Musical Arts In Africa* 1, no. 1 (2004): 1-23.

Discusses cerebral differences between experienced and inexperienced sight-readers. In general, experienced sight readers can integrate the various mental functions into one task much easier than the inexperienced, who rapidly flip between reading the score, interpreting rhythms, finding pitches, pressing keys, etc. Proves that sight-reading is a concrete skill, and, while tied to overall musicianship, can absolutely be developed independently and intentionally. From a pedagogical viewpoint, the author argues that we can and should construct sight-reading skills (constructing meaningful music on the spot) as opposite to normal performance skills (constructing music from memory). Strikes a balance between heady, scientific jargon and lightweight fluff.

Grahn, Jessica A., and Dirk Schuit. "Individual Differences in Rhythmic Ability: Behavioral and Neuroimaging Investigations." *Psychomusicology: Music, Mind & Brain* 22, no. 2 (December 2012): 105-121.

Considers three factors in rhythm reproduction: auditory short term memory, sensitivity to irregularities of rhythm, and musical training. Participants of the study were asked to complete various tasks in between hearing and repeating a rhythm, to determine which type of task would interfere with short term memory. Drawing a square did not hamper accurate reproduction, but silently mouthing vowels did, as this area of the brain is more closely related to auditory processing. The takeaway for a music educator is that people vary widely in their ability to internalize, relate to, and reproduce rhythm. Musical training will aid anyone, but there is strong evidence for some genetic basis. Expecting that every student in a music class will feel the beat is a mistake.

Groussard, Mathilde, Renaud La Joie, Géraldine Rauchs, Brigette Landeau, Gaël Chételat, Fausto Viader, Béatrice Desgranges, Francis Eustache, and Hervé Platel. "When Music and Long-Term Memory Interact: Effects of Musical Expertise on Functional and Structural Plasticity in the Hippocampus." *Plos ONE* 5, no. 10 (October 2010): 1-8.

Dense discussion of brain areas and functions. Research is meticulous and well done. Would require translation for the non-neuroscientist music educator. Supports the notion that musical training can improve memory and stave off brain-degenerative disease. Differentiates between recollection and familiarity (the primary distinction being a link to autobiographical material). Suggests that trained musicians create stronger, more detailed episodic and emotional attachments to music they know. Good information for any musician to know, particularly to supplement memorization techniques.

Hayward, Carol M., and Joyce Eastlund Gromko. "Relationships Among Music Sight-Reading and Technical Proficiency, Spatial Visualization, and Aural Discrimination." *Journal Of Research In Music Education* 57, no. 1 (April 2009): 26-36.

Outlines predictors of good sight-reading from a list of possible variables. In general, the strongest sight-readers have the widest range of mental approaches at their disposal. For example, fingering along with recorded music is a huge benefit, as is toe-tapping to keep the beat while sight-reading, building a physiological sound image of the passage with solfege, and integrating other auditory, visual, and kinesthetic activities. The links amongst spatial reasoning, pattern detection, and auditory processing is compelling. Fascinating read, and quality exercises for students can be developed from Hayward's work.

Herholz, Sibylle C., Claudia Lappe, Arne Knief, and Christo Pantev. "Neural Basis of Music Imagery and the Effect of Musical Expertise." *European Journal Of Neuroscience* 28, no.

11 (December 2008): 2352-2360.

Tentatively shows that musical training allows for stronger imposition of intent on future music. The clear mental image in musician's brains allows them to determine mismatched notes “instantly,” in neural pulse terms. When played part of a melody and asked to imagine the next note, musical training correlated with strength of expectation and eventual correctness of the note in question, when it was performed either accurately or not. Could be incorporated into an overall philosophy of teaching, performing, and studying music with conviction. Likely intended to be a preliminary study, but well done.

Higuchi, S., H. Hall, N. Roberts, S.B. Eickhoff, and S. Vogt. "Imitation and Observational Learning of Hand Actions: Prefrontal Involvement and Connectivity." *Neuroimage* 59, no. 2 (January 16, 2012): 1668-1683.

Proves that motor action imitation alone is insufficient for learning, and that imitation serves as “raw material” in the rear of the brain for higher-order thinking in the front. Explores similarities and differences in the amount of time it takes people to finger a guitar chord when prompted with a chord symbol, based on the amount of physical or observational practice they have had. Reinforces similar findings of neural efficiency after a task has been mastered, with less brain power required for more experienced guitarists. Takeaway from Higuchi's work is that mimicry is a great method of starting to learn a new skill, but, by itself, is insufficient for musical mastery.

Marie, Celine, Takako Fujioka, Leland Harrington, and Laurel J. Trainor. "The High-Voice Superiority Effect in Polyphonic Music is influenced by Experience: A Comparison of Musicians Who Play Soprano-Range Compared With Bass-Range Instruments." *Psychomusicology: Music, Mind & Brain* 22, no. 2 (December 2012): 97-104.

Shows that musicians trained in bass-range instruments devote more of their brain to hearing, interpreting, and predicting these lower pitches, compared with the rest of the population, in which significantly more mental energy is devoted to the highest (and usually most melodic) voice present. Also shows how preferred method of learning music effects pitch discrimination, with those who learn by ear showing the most overall competence. Narrow immediate applications, but could absolutely motivate someone to study a bass instrument, in order to “stretch their ears” down to the low range of musical pitches. Most applicable to musicians who need to listen intently to a bass line; great article for jazz educators.

Merrett, Dawn L., and Sarah J. Wilson, “Music and Neural Plasticity.” *Lifelong Engagement with Music* (2012): 119-159.

Written with curious laypersons in mind, and provides enough background for both non-musicians and non-scientists. Explains why musicians are ideal models of training-induced neuroplasticity. Generalizes physical changes that come with musical training, and explains how the brain may develop differently, depending on the primary instrument of study.

Touches on correlations between brain structure and absolute pitch. Findings on auditory processing reinforce the notion that more efficient processing can take place after extended training, including (and especially) mental practice away from the instrument. Short term, intensive training still reaps some lasting benefits for anyone. Quality overview; references classic works in the field.

Petrini, Karin, Frank E. Pollick, Sofia Dahl, Phil McAleer, Lawrie McKay, Davide Rocchesso, Carl Haakon Waadeeland, Scott Love, Federico Avazini, and Aina Puce. "Action Expertise Reduces Brain Activity for Audiovisual Matching Actions: An fMRI Study with Expert Drummers." N*euroimage* 56, no. 3 (June 2011): 1480-1492.

Thorough study uses an fMRI to explore the ability to recognize audio-visual synchronicity and congruency. Expert drummers were compared to non-musicians. Research is aimed at those with considerable background in brain anatomy, though findings have valuable applications for music teachers. First to discover that disparate neural networks are used for recognizing synchronicity and recognizing congruency. Well-practiced musicians were found to use less brainpower (more efficiently) to determine how well audio and video correspond. This has implications for practice regimens, teaching how to follow a conductor, and error detection and correction. Also explains why musicians outperform non-musicians in some daily life, “non-musical” tasks, and references several relevant studies. Article could refine a musician's thinking about the visual aspects of performance.

Pfordresher, Peter Q., and James T. Mantell. "Effects of Altered Auditory Feedback Across Effector Systems: Production of Melodies by Keyboard and Singing." *Acta Psychologica* 139, no. 1 (January 2012): 166-177.

Pfordresher has written extensively on related topics. Tests the abilities of people to perform accurately when they are also hearing a delayed and altered version of their own performance. Currently interesting to neuroscientists, but further research into the brain mechanisms at work could have applications for music educators taking their groups to perform in challenging acoustic environments (windy football field, gymnasium, unfamiliar concert hall) or, more generally, in handling distractions during a musical performance.

Quinn, Michael. "Shock to the Brain 'Boosts Musical Ability'." *Classical Music* no. 825 (October 28, 2006): 8.

A summary on a study of neurobiotics and musicianship. Students who were trained to control low-frequency theta waves reported increased creative freedom away from their instrument. Shows without a doubt that the state of the brain has real, profound, physical and musical effects. Impractical for the public school, K-12 music educator for ethical reasons, but nonetheless fascinating. Could open up musical opportunities for children with deep anxiety issues or other mental barrier.

Tervaniemi, Mari. "Musicians—Same or Different?." *Annals Of The New York Academy Of*

Sciences 1169 (July 2009): 151-156.

Proves that, to the limited scope of the study, instrument choice effects the cognitive benefits derived from the study and practice of music. For example, violinists tend to be highly sensitive to intonation: more sensitive than the average musician, who is still more sensitive than most non-musicians. Conductors scored the highest on a test of determining which of six loudspeakers is emitting a tone. One result could be that the study of a secondary instrument could be hugely beneficial to overall musicianship. Also aids in the desire for educators to be sensitive to students' differences in aptitude, across all areas of musicality, learning ability, and talent. Highlights and explains differences is a group of people that may otherwise be inaccurately homogenized.

Thaut, Michael H. "The Neural Dynamics of Rhythm." Chap. 3 in *Rhythm, Music, and the Brain: Scientific Foundations and Clinical Applications.* New York: Routledge, 2005.

Explores beat synchronization, how quickly and in what ways people adapt to changing tempi. Posits theories for where internal sense of pulse "comes from." Finds that more complex rhythms are literally more cerebral, as the cerebellum becomes more active when musicians perform hemiolas. Questions the assumption that there is anything biological about starting, pedagogically, with a large note value, and dividing it up evenly. Many Eastern cultures use additive rhythmic schemes, and Thaut finds ample evidence for their neurological validity. Fascinating, informative, more theoretical than immediately applicable.

Vlek, R.J., R.S. Schaefer, Gielen, C.C.A.M., J.D.R. Farquhar, and P. Desain. "Shared Mechanisms in Perception and Imagery of Auditory Accents." *Clinical Neurophysiology* 122, no. 8 (August 2011): 1526-1532.

Studies the ability of people to superimpose imaginary accents over a provided metronomic tempo. Demonstrates that people are able to encode musical intention into their thoughts. Proves that generating musical intent is more strenuous on the brain than listening to music. A healthy amount of mental effort serves the brain well. More of interest to scientists than musicians or teachers; could be used to prove the worth of mental practice.

II.

Allen, Sarah E. "Beyond Learning Styles." *Southwestern Musician* 78, no. 8 (April 2010): 28-32.

Condenses brain research into immediately applicable music teaching strategies. Refines the notion that blocked practice (several repetitions of one skill before moving to the next) is most effective in the early stages of acquiring a new skill, but varied practice is more effective later on. Calls our attention to kinesthesiolopgy. Verbal instructions which focus the student on sound have proven more useful than those which ask a student to focus on specific muscle movements. Students need our feedback, but not after every repetition. Doing so can suppress their self-assessment, and they may become too reliant on external feedback. Valuable, concise article which updates and improves the knowledge of the working music teacher.

Allison, Joseph, and Erin Wehr. "Brain Rules for Rehearsals." *School Band & Orchestra* 14, no. 5 (May 2011): 14-17.

Discusses John Medina’s twelve brain rules (every brain is wired differently, we all have the capacity to explore, etc.) as they could be applied to music education. Rather than presenting completed research and hard-and-fast “rules for rehearsals,” article is brief, more thought-provoking than informative or conclusive. Further research along these lines could reap massive benefits. As teachers, the presentation of Medina's writings is worthwhile on its own merit.

Chappell, Sally. "Developing the Complete Pianist: A Study of the Importance of a Whole-brain Approach to Piano Teaching." *British Journal Of Music Education* 16, no. 3 (November 1999): 253-262.

Argues that, in the course of a musician's training, musical skills are often emphasized in a detrimental order. Developing the entire brain by including memorization, improvisation, and internalization early on could remedy this, and enable greater creativity, flexibility, and capacity for musical expression. Internalization of a difficult passage can even make possible one which was unplayable by the student before, due to muscular tension associated with uncertainty. Compelling argument for teaching the larger scope of musicianship before a students becomes too bound up in notation, technique, and playing exams. Posits that teacher-student relationships would also tend to be healthier if more of the learning is intuitive and student-directed. Chappell comes across as one intimately familiar with the current state of many music curricula.

Collins, Anita. "Neuroscience Meets Music Education: Exploring the Implications of Neural Processing Models on Music Education Practice." *International Journal Of Music Education* 31, no. 2 (May 2013): 217-231.

Translates Koelsch's model of music processing in the brain into usable material for teachers. Aims to educate students to the point of being able to unravel the mysteries of a piece of music on their own. Explains discrepancies and counter-intuitive practice with regard to what current mental models tell us SHOULD work, and what methods music educators succeed with. Breaks down the different levels of complexities of mental processing that occurs when dealing with music, and rough estimations of the ages at which they emerge. These findings often contradict the conventional “order of operations,” as musicians tend to learn best when starting with bodily movement, and this is the last step in Koelsch's model. Collins's work could be of immense value to anyone designing a music curriculum or assessment.

Gruhn, Wilfried. "Body, Voice, and Breath: The Corporeal Means of Music Learning." *Orff Echo* 42, no. 3 (Spring 2010): 34-37.

Gruhn suggests that coordination, intonation, and the feeling of pulse in children are physically interrelated. He explains that, because children experience the passing of time as fairly fluid (opposed to adults, who tend to meter out time with clocks and schedules, into chunks), savvy educators of young students can tap into this by turning musical learning into a concrete, bodily experience. While his research is focused on children ages 3-5, extrapolations can be drawn to inform the teaching of young band students, who still benefit from stronger brain-body connections. The article feels vague and theoretical, but could lead to educators asking better questions of neuroscientists.

Helton, Benjamin. "Rhythm and the Brain." *Instrumentalist* 67, no. 4 (November 2012): 31-33.

Weds the “sound before symbol” approach with the notion that internal pulse is already developed by the time children are walking and coordinating basic motor functions. If the cerebellum is comfortable with a rhythm, its notation will not be such an obstacle. Helton states, “I think of teaching from the back of the brain forward” (the back of the brain, generally, takes in information, and the front forms novel thoughts). When performing highly syncopated and unfamiliar rhythms, we must “distract” the brain with subdivisions, so it does not try (and fail) to anticipate the next note. While only a graduate student at the time of publication, and although there is not much original research presented, the educational concepts are novel, practical, and seemingly efficient.

Hodges, Donald A. "Can Neuroscience Help Us Do a Better Job of Teaching Music?." *General Music Today* 23, no. 2 (January 2010): 3-12.

Provides a practical, cyclical model of learning: Sense, to Integrate, to Act. Perhaps geared towards younger children, but topics have broad applications. Explains audiomotor neural networks and the link between motor networks and pleasure centers. Article is interspersed with teaching suggestions. Encourages fun in learning, because this can physically addict a person to learning. Encourages connecting learning to emotions, and multisensory learning, both for similar reasons. Presents sound evidence for both repetition of musical concepts and exposure to novel musics. Practical suggestions for utilizing the brain's short term (both declarative and procedural) memory in rehearsal. Compelling evidence, related to myelin sheathing, for periodically providing some time for students to decompress, and process new material. Also relates to the balance of input teachers can constructively give at one time, before it is “in one ear and out the other.”

Jensen, Eric. *Music with the Brain in Mind.* Thousand Oaks, California: Corwin Press, 2000.

Equal parts music cognition primer, music therapy, and educational best practices. Easily digestible book. Interspersed are brief vignettes, entitled “on a practical note.” While known as a gold mine for music and arts programs advocacy in schools, Jensen provides quality information in an accessible format. Helpful suggestions for using background music in any classroom, to various effects. Suggests ways of incorporating novel activities into a music classroom, with proven brain-boosting benefits. Not the most thorough source for any one aspect of music and the brain, but valuable nonetheless for its breadth, brevity, and creativity.

Milanese, Chiara, Gabriella Facci, Paola Cesari, and Carlo Zancanaro. “Amplification of Error”: A Rapidly Effective Method for Motor Performance Improvement.” *The Sports Psychologist* 22, (2008): 164-174.

Sets forth an innovative approach to error correction in motor performance. The researchers tested a relatively simple (compared to playing a musical instrument) task: the long jump. Dubbed the “Method of Amplification of Error,” it works like this: the teacher identifies the most prominent inefficiency in the student's technique, the student exaggerates that error, then applies that feeling to the next “real” attempt. So many musical tasks require a sensitivity to the spectrum of possibilities that this kind of practice could “stretch the ears” and muscles of beginning musician. Learning to play an instrument has a physical side that is tied directly to brain development. The authors present their findings here mostly as fact, without suggestions for their application. However, there is more than enough detail of the process itself for any working music teacher to draw up their own, likely instrument-specific, exercises.

Persellin, Diane, and John W. Flohr. "Applying Brain Research to Classroom Strategies." *Southwestern Musician* 79, no. 7 (February 2011): 27-33.

Practical set of established conclusions from brain research, and suggestions for their application in the band room. Presented well, as far as “Reader's Digest” versions go. Solid references throughout, and easy to follow Persellin's train of thought. Fine point of departure for the curious music educator. Persillen has researched music and neuroscience extensively.

Reimer, Bennett. "New Brain Research on Emotion and Feeling: Dramatic Implications for Music Education." *Arts Education Policy Review* 106, no. 2 (November 2004): 21-27.

Originally presented as an MENC speech. Discusses variability of brains from person to person, which confirms what contemporary educators have been saying. Also differentiates the activated brain areas in beginner vs. professional musicians. Thorough investigation of “emotional competent objects” and music. Explains how a “critical pitch” of the nervous system pushes an experience above the threshold of feeling. Ongoing brain development allows us respond differently to the same recording. Relevant to today's music educator, demonstrates that each national standard of music education activates a different combination of brain areas. Contests Gardner on some valid, research-backed points. Great article for integrating the emotional impact of music with educational philosophy and practice.

Schlosser, Milton. "Minding the Music: Neuroscience, Video Recording, and the Pianist." *International Journal Of Music Education* 29, no. 4 (December 2011): 347-358.

Schlosser takes a fresh angle on performance anxiety, by using the power of neuroscience to inform objective post-performance video reviews. Gives concise history of usage

of still images and videos in sports psychology, and the relative effectiveness of various approaches. Demonstrates that errors are more prominent in short term memory. Young music students often do not have the skills to cope with poor performances. The author has developed a Recital Review Protocol. This introduces novel ideas of teacher involvement in reflecting on a performance. Reaffirms findings on audio/visual relationships (whether beneficial or harmful). Suggests ideas for further research (camera angle, time interval between performance and first viewing). Deserves reflection from anyone who coaches performers, particularly music teachers operating a private studio and hosting recitals.

Schons, Suzanne. "What's Going on in There? How Students Learn." *Keyboard Companion* 19, no. 1 (Spring 2008): 32-35.

Written with the working teacher in mind. Schons is not a scientist, but presents insights from relevant neuroscience in a practical manner. Good suggestions, clear reasoning throughout. Considers learning and retention from the student's perspective, particularly with young teenager's attention spans. Ideas include switching gears (as the brain attends better to novel stimuli) and promoting wakefulness in your teaching space (providing water and fruit, standing up and stretching). Explains why, on the level of neural pathways, “practice makes permanent,” and why it is so vital to attend to musical details early on. Argues for the inclusion of music theory instruction, as it aids in the chunking of ideas when studying a piece.

Sternbach, David J. "Ear Training Can Enhance Consistency and Reduce Repetitive Overuse Injuries." *American Music Teacher* 58, no. 6 (June 2009): 70.

Argues that imagining a better version of a performance or technique is much more effective than physically, repeatedly, practicing it poorly. For students with inadequate audiation skills, playing a passage repeatedly can seem like the only way to learn music. Unfortunately, the erroneous repetitions encode mixed messages in their brains. Cultivating ear training has proven to be a worthwhile investment of practice time, as hearing a passage correctly is among the strongest indicators of producing it accurately on an instrument. Sternbach lends a unique perspective, as both a professional hornist and practicing psychotherapist. Provides ample justification for offering theory and aural skills classes for middle and high school musicians.

Stewart, Lauren, and Aaron Williamon. "What are the Implications of Neuroscience for Musical Education?." *Educational Research* 50, no. 2 (June 2008): 177-186.

Argues that the ability to perform an instrument or sing is merely the “icing on the cake” of musical cognitive ability, sometimes existing independently of the ability to interpret and appreciate music in a complex way. Stewart finds that rhythm and pitch in notation are processed separately, despite the tendency of many musicians to combine the two. This should come as no surprise; most of our daily experience of the world is due to our brain synthesizing information. In musicians with adequate experience reading notation, the mere presence of notation, even if it is garbled, computer-generated nonsense, activates a “notation reading” sequence in the brain. A very pinpointed, focused read. Fascinating for those who teach music appreciation, beginning piano for adults, etc.

Telesco, Paula. "Teaching Elementary Aural Skills: How Current Brain Research May Help." *Journal Of Music Theory Pedagogy* 27 (October 2013): 211-245.

Argues that current approaches to aural skills pedagogy are out of line with the experiences students in these classes typically have. While directed at those teaching college music majors, Telesco's thoughts on musical schemata are perhaps even more applicable at the beginning band level. Presses for the revival of a common musical repertoire to establish an equally shared feeling for tonality in children. Addresses the issue of non-vocalist musicians believing they are amusical, for their lack of audiation accuracy. Reinforces the established "sound before symbol" approach. Presents neuroscience evidence for various instructional methods. Takeaway message is condensed to four points of consideration when starting a student on aural skills. Useful material for a subject matter that is at risk of being treated too loosely.

All sorts of music can have a positive effect on the brain. Researchers from UK and Finland have discovered that listening to sad and gloomy music is pleasing to people and improves their mood. Moreover, they begin to feel more comfortable, as the music makes them contemplate their experiences. The scientists have pointed out the paradox: people tend to experience a strange satisfaction after theyâ€™ve emotionally reacted to tragic art, be it music, cinema, paintings or others. Japanese psychologists have proposed that the explanation for this phenomenon is due to how people associate sadness wi Musical training has recently gained additional interest in education as increasing neuroscientific research demonstrates its positive effects on brain development.Â Frontiers in Neuroscience. Auditory Cognitive Neuroscience. Toggle navigation Section. (current)Section.Â (2005) recruited 50 children who were about to begin their musical education and compared them with a group of 25 age-, socioeconomic status and verbal IQ-matched controls.Â It appears, therefore, that instrumental music training may aid the acquisition of spatial abilities in children rather than bring about a permanent advantage in musicians. Finally, Schlaug et al. Instruments Music Production Music Fundamentals Vocal Music Techniques Music Software Other Music. Teaching & Academics. Engineering Humanities Math Science Online Education Social Science Language Teacher Training Test Prep Other Teaching & Academics.Â Here is a little secret: I wasn't interested in neuroscience from the beginning. Instead, I started as a psychologist. But if you are interested in understanding the human mind then sooner or later this leads you to the brain. Once I realized how much neuroscience can teach us about ourselves, I was hooked and found myself more and more in this discipline. I realized that neuroscience is not as complicated as it seems and extremely fascinating. Neuroscience to Music Education: An Overview of Current Research, and Implications. for Pedagogy and Policy. By.Â After neuroscience. provided evidence of brain plasticity or neuroplasticityreorganization of neural. pathways in the brain caused by experience (Flohr, 2010)research began to provide. evidence that the brain can adapt, which requires all neurons to fire from different areas. Beyerstein (as cited by Geake, 2008) explains that evolution does not produce excess