by Donald J. Walter and Jennifer S. Walter

Skill Development

How Brain Research Can Inform Music Teaching

Abstract: Practice is a major element in cultivating musical skill. Some psychologists have proposed that deliberate practice, a specific framework for structuring practice activities, creates the kind of practice necessary to increase skill and develop expertise. While psychologists have been observing behavior, neurologists have studied how the brain changes when people learn. Neurologists have found changes in the structure of the white matter of the brain that correlate with vast amounts of musical practice. This article contains a brief overview of what researchers believe happens in the brain when people learn or refine motor skills, such as singing or playing an instrument. This article also explores the new research into myelination, one mechanism the body uses to optimize the efficiency of neural circuits. In addition, the authors propose ways that music educators can use findings from both psychological and neurological fields to improve music teaching and learning and help their students begin to develop musical expertise.

Keywords: brain research, deliberate practice, musical expertise, myelination, neurology

What happens in the brain when a person practices music intensely over time? This article offers some insight.

What leads to expertise? How do accomplished musicians cultivate their ability to perform at such a high level? In this article, we will discuss one theory about how musicians develop expertise and provide a brief overview of current brain research into motor skill development with specific exploration of the role of myelin. Finally, we will make suggestions to music teachers on how they can apply these ideas to their teaching. In particular, we will present ideas about how teachers can structure student practice activities to take advantage of current research on the practicing brain.

How Do Musicians Develop Expertise?

Aside from the common beliefs in innate talent or "musical genes," two popular ideas about how people become expert musical performers are the "10,000-hour rule" and deliberate practice. Researchers first proposed the 10,000-hour rule—the idea that an individual has to spend at least 10,000 hours over the course of ten years to achieve mastery of a discipline—in an examination of chess players. In 1973, psychologists Herbert A. Simon and William G. Chase studied the amount of time chess grandmasters

Donald J. Walter is the senior director of bands and orchestras at Northwest Guilford Middle School in Greensboro, North Carolina. He can be contacted at walterd2@gcsnc.com. Jennifer S. Walter is an associate professor of instrumental music education in the School of Music, Theatre and Dance at the University of North Carolina at Greensboro. She can be contacted at jlstewa7@uncg.edu.

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participated in chess activities before they achieved grandmaster status.[1] They found that, on average, the grandmasters spent about ten years and between 10,000 and 50,000 hours developing their skills.

After Chase and Simon published their article, researchers in other fields looked for the same pattern. In the 1990s a group of psychologists led by Anders Ericsson studied the amount of time expert performers spent on gaining expertise.[2] First, the group reviewed the relevant research literature from many domains, including chess, music, psychology, science, sports, telegraph operating, typing, and writing. They found that accomplished performers in all of these fields seemed to have spent at least 10,000 hours developing expert performance in their disciplines. The results of their review supported both the idea that people developed expertise over time and that the amount of practice was an important element. However, these correlations did not necessarily prove causation. Ericsson and his group had difficulty believing that simple "time on task" was the only factor that influenced expert performance.

After the review of existing research, Ericsson's group conducted a descriptive study by examining the activities completed by violinists at a music conservatory.[3] They found that only certain activities promoted an increase in skill. They referred to each of these activities as "deliberate practice," which they described as a well-defined task, at an appropriate level of difficulty, accompanied by formative feedback, and also accompanied by opportunities to apply corrections and complete repetitions. The group concluded that people have to engage in deliberate practice activities for at least 10,000 hours to achieve expert performance at the international level. Since 1993, Ericsson has continued to examine and apply deliberate practice principles in a wide variety of venues such as medicine, business, music, and sports. He has authored or coauthored numerous journal articles and coedited *The Cambridge Handbook on Expertise and Expert Performance*.[4]

Lately, the popular press has begun to include articles that examine the concept of deliberate practice. Journalists have written pieces in newspapers and magazines about deliberate practice in relation to sports, music, and business.[5] Moreover, the authors of books such as *Outliers*, *Talent Is Overrated*, *The Genius in All of Us*, and *The Talent Code* have championed the belief that deliberate practice is a foundational element in the development of expert skill.[6] Not everyone agrees, however, that deliberate practice is the key to superior performance. The crux of the debate is Ericsson and colleagues' oft-repeated claim that deliberate practice is both necessary and *sufficient* to explain expert performance. In one notable study, David Z. Hambrick and his colleagues used statistical modeling techniques to examine how much of the variation in performance between experts in chess and music was attributable to the amount of deliberate practice.[7] They found that deliberate practice accounted for about 30 percent of the difference. Other researchers have come to similar conclusions: Robert A. Duke, Amy L. Simmons, and Carla D. Cash published a journal article titled "It's Not How Much, It's How" that examined the practice activities of keyboardists working with a new melody.[8] They found that the most accomplished performers used the greatest variety of practice techniques but did not spend the most time practicing. These performers got more done in less time than the least accomplished performers. The takeaway is that practice is important for skilled performance but may not be the only factor.

How Does the Brain Change When People Practice?

While psychologists and other researchers have conducted investigations into what people do to become expert performers, neuroscientists have been studying the brain to understand what happens "inside the head" when people learn. For more than one hundred years, brain researchers have focused their study on neurons, the cells that carry nerve impulses throughout the brain and body.[9] Researchers have found that when someone learns a new motor skill, neurons in the brain create connections with other neurons at junctions called synapses.[10] These synaptic connections link neurons together to create neural circuits that allow for complex actions. When people engage in many repetitions of an action, they strengthen their synaptic connections and create stable circuits for well-learned motor programs.[11] In other words, "Neurons that fire together, wire together."[12]

In the past ten years, some scientists have begun to focus their study on nonneuronal cells in the brain called glial cells.[13] For a long time, scientists considered glial cells merely to be the "glue" that holds neurons together. However, new research has demonstrated that glial cells play an active role in maintaining the health of neurons. In addition, they create myelin, a substance that plays a crucial role in regulating the speed with which neurons carry their messages.[14] (See Figure 1 for short definitions of some neurological terms.)

One researcher who has spearheaded the investigation into glial cells and myelination is Dr. Douglas Fields, chief of the Nervous System Development and Plasticity Section at the National Institute of Child Health and Human Development.[15] Fields has written extensively about cutting-edge research into glial cells and myelin. In his book, *The Other Brain*, he makes the case that more than half the brain is made up of glial cells and that discovery of what these cells do is crucial to improving our understanding of how the brain functions.[16] Fields does not discount the role of neurons in learning, but he wants to ensure that the role of glial cells is not overlooked.

What Is Myelin?

Myelin is a white, fatty tissue that glial cells wrap around the long tails of neurons, called axons.[17] Axons carry messages from neurons in one part of the brain to neurons in another part.[18] Axons coated in myelin (myelinated axons) carry neural messages more easily, more quickly, and more efficiently

FIGURE 1

Some Neurological Terms

Axon: The long tail of a neuron. Axons carry messages away from the neuron body.

Glia: A class of cells that support the growth, health, and function of neurons. Glial cells are found throughout the brain and body.

Myelin: White, fatty tissue that glial cells wrap around neurons. The structure of myelin plays an important role in how neurons pass messages down their axons.

Myelination: The process by which glial cells wrap axons with myelin. Myelination happens as people mature and is influenced by what people do.

Neural circuit: A group of neurons that fire in concert to perform a complex action.

Neural impulse: Messages that are sent through the nervous system as electro-chemical signals.

Neuron: Type of cell that makes up the nervous system. Often imagined as being like a wire.

Synapse: The location where two or more neurons meet.

White matter: The inner portion of the brain that consists of myelinated axons.

than axons that do not have a myelin coating. The inside of the brain, called the white matter, consists of myelinated axons. Brain scientists have found that highly trained individuals such as musicians have differences in the structures of the white-matter portion of their brains when compared to this brain area in nonmusicians. These differences correspond to the age at which the musicians began serious practice.[19]

The process of glial cells wrapping myelin around axons is called myelination. Myelination is a maturational process that is influenced by what a person does.[20] As a person grows and matures, glial cells coat the axons inside of the brain with myelin. This occurs rapidly during childhood, continues at a quick pace through adolescence, slows considerably in the mid to late twenties, and continues more slowly for the rest of a person's life. Driven by genetic instructions, myelination happens in different portions of the brain at different times. Along with other brain-organizing processes, myelination during brain maturation may help determine "critical" or "optimum" learning periods during which an individual may acquire particular skills more easily than at other points throughout life.[21]

What Does Myelin Do?

As neural insulation, myelin prevents neural impulses from leaking away from the axon.[22] A useful analogy might be the insulation around a hot water pipe. An uninsulated pipe will let heat from the hot water radiate into the environment. However, if the pipe is wrapped in layers of insulation, less heat will escape from the pipe into the environment. The same idea applies to axons and myelin. An axon that is insulated with myelin leaks less electric charge than an un-insulated axon; therefore, a smaller charge can be sent to transmit the same information.[23] Less energy is needed to fire a myelinated neural circuit.

As a timing mechanism, the structure of the myelin sheath affects the speed and coordination of how axons carry neuronal messages.[24] Axons that are not myelinated carry their messages in slow waves at about 2 miles per hour. Conversely, messages in a well-myelinated axon jump from point to point along the axon and move much more quickly—perhaps as fast as 200 miles per hour.[25] The structure of the myelin sheath also regulates the speed of neuronal impulses so that they get to their destinations at precisely the correct time.[26] Neurons are located in different parts of the brain, so the axons that make up a neural circuit may be of varying lengths. Myelination allows the brain to regulate the speed of neuron transmission so that impulses from different places can arrive at the appropriate synapse at the same time.[27] When impulses arrive at the synapse at the same time, the synapse "fires" and passes the message to the next link in the neural circuit. If the impulses arrive at different times, the synapse will not fire, the message will be lost, and the desired action will fail.

What Does This Have to Do with Music Teaching?

Peoples' actions and experiences influence myelination.[28] When glial cells notice that a particular neural circuit is being fired repeatedly, such as when someone practices a motor skill, they wrap the axons in that circuit with myelin.[29] The more a person uses the neural circuit, the more myelin wrapping the glial cells apply. This process takes time, perhaps days or weeks, but ultimately, it could result in a frequently used axon gaining up to 150 layers of myelin.

In his book *The Talent Code*, Daniel Coyle examines the intersection between research into myelin and deliberate practice.[30] Following his example, we will present a practice activity that meets the criteria for a deliberate practice exercise. After presenting the sample activity, we offer a summary of how the brain may change when students have completed the practice activity. Finally, we will discuss the possible implications for music teaching.

First, deliberate practice is a well-defined task. For musical practice, this is the difference between a global statement such as "make it sound better" and a more specific statement like "correct the intonation of the C-sharp located on the G string of the viola." Second, the well-defined task must be at an appropriate level of difficulty. The target task should be slightly beyond what a music student can already accomplish but not so far beyond as to be unattainable. For example, a teacher may decide that having a class of beginning viola students practice stretching from a C-natural to an in-tune C-sharp on the G string of a viola is an appropriate level of difficulty. Third, completion of an appropriately difficult task must be accompanied by formative feedback. Students must know if they have met the performance goal. Beginning students probably cannot judge if the C-sharp is in tune, so the guidance of a teacher or a tuner would be helpful. Fourth, students need opportunities for repetition and correction. Once a teacher provides formative feedback, the students must have the opportunity to apply that feedback to correct or reinforce their performance. The students must be given the luxury to try and try again.

After identifying an appropriately difficult task, the teacher designs an activity for supervised practice. In this case, the activity might consist of a short drill in which the students practice stretching their fingers from C-natural to C-sharp on the viola's G string. He or she will have the students practice this stretch while other students play an A-string drone. After each attempt, the teacher will tell the students if they have reached the goal of an in-tune interval. Of course, the ultimate goal is to have the students be able to discern this for themselves, but for now, the teacher is providing the feedback. If the students miss their goal, the teacher offers them suggestions on what to do differently. If they achieve the goal, he or she will provide specific praise and have them repeat the drill a few more times to cement the learning. An important element for the teacher to remember is that this activity is not a one-day quick fix. Instead, the teacher must have the students complete this drill many times over the course of several days. Only when the skill is repeated with consistently correct outcomes has it truly been learned.

As the students practice changing their hand shape to reach the C-sharp, they are sending messages through the neurons in their brains and bodies. As a response to these messages, the neurons create connections with other neurons.[31] As the students repeat their actions, they are strengthening the connections and making them resistant to change. The neurons are "wiring together." As the students continue to practice the exercise over the course of many days, the glial cells in their brains begin to wrap the axons with myelin.[32] As the myelin accumulates, the students improve their coordination for this exercise. They become better able to carry out the stretching motion. The myelin has made using this particular neural circuit easier. For the students, making the stretch takes less effort and becomes automatic.

Therefore, after practicing the C-sharp drill, students will be able to expend less energy to send the signals to their hands to form the correct shape to play C-sharp. They will not have to think as hard as they did before practice to form the correct hand shape. In addition, the more students practice the desired performance skill, the smoother the motions are that move their hands into the shape needed to form a C-sharp. Finally, the students will be able to form the practiced hand shape more quickly because they have increased the speed with which the neural circuitry carries the messages to create that shape. In short, the action will have become automatic.[33]

Implications for Music Teaching and Learning

Teachers and students must take care to determine and practice only desired actions because the processes of synaptic strengthening and myelination do not discriminate between "good" and "bad" actions.[34] The body will make automatic whatever is done repeatedly. Understanding this fact may cause teachers to rethink the traditional approach of using time-based practice assignments. Teachers interested in further reading about brain research might benefit from looking at the websites listed in Figure 2.

Teachers should take care to have students practice with purpose, that is, with clearly defined goals that the student can evaluate for success.[35] This is a very different approach to independent student practice than having students simply log time on a practice chart. Individual practice should be used to refine and cement desired skills, not take a shot in the dark at figuring out a technical challenge; unless, of course, solving a particular challenge is the point of the homework assignment. One approach to focus student effort would be the use of a checklist that delineates desired practice outcomes (see Figures 3 and 4).[36] Using such a checklist allows the teacher to focus students' attention on what goals should be accomplished during student practice. No longer are students sent off on their own with just a vague charge to "make it better." Instead, they are provided with a navigator to guide them in their work.

FIGURE 2

Further Reading Online

http://www.brainfacts.org – a website about topics in neuroscience for the general public

http://www.huffingtonpost.com/dr-douglas-fields/ – Dr. Field's Huffington Post Blog

http://neuroscience.nih.gov/index.html – the National Institutes of Health Neuroscience page

http://thetalentcode.com – Daniel Coyle's blog about expert coaching

http://www.psy.fsu.edu/faculty/ericsson.dp.html – Dr. Anders Ericsson's publications page at The Florida State University

FIGURE 3

Clarinet Practice Checklist

Use this checklist to help you prepare your playing assignment:

Name ____

What are you practicing? ______________________________

Musician's Posture: Are you ...

❑ Sitting on the front edge of your chair?
❑ Placing your feet under or behind your knees?
❑ Sitting up straight?

Tone: Are you ...

❑ Making a resonant (strong) sound?
❑ Making a clear sound?

Pitch: Can you ...

❑ Say the letter names for each pitch?
❑ Put down the correct finger(s) for each pitch?
❑ Produce each pitch consistently?

Rhythm: Can you ...

❑ Count and clap the rhythm?
❑ Say or sing each pitch name in rhythm?
❑ Finger the notes in rhythm?
❑ Play each pitch and rest in rhythm with a steady pulse?

Articulation: Can you ...

❑ Identify all the printed articulations?
❑ Perform all the printed articulations?

Fluency: Can you ...

❑ Play the entire excerpt, without mistakes, in one try?
❑ Play the entire excerpt, without mistakes, three times in a row?

[Teachers can use a checklist like this to focus students' practice on a variety of technical or musical elements. Some other ideas include style, dynamics, expression, or character.]

FIGURE 4

Some Resources for Guiding Student Practice

Barden, Wendy. *Practice and Reflection in Band and Orchestra.* San Diego, CA: Kjos Music Press, 2010.

Coyle, Daniel. *The Little Book of Talent: 52 Tips for Improving Your Skills.* New York: Bantam, 2012.

Froseth, James. *The Home Helper.* Chicago, IL: GIA Publications, 2006.

Johnson, Darren. "More than Just Minutes: Using Practice Charts as Tools for Learning." *Music Educators Journal* 95 (March 2009), 63–70.

Oare, Steve. "Practice Education: Teaching Instrumentalists to Practice Effectively." *Music Educators Journal* 97 (March 2011), 41–47.

Prichard, Stephanie. "Practice Makes Perfect? Effective Practice Instruction in Large Ensembles." *Music Educators Journal* 99 (December 2012), 57–62.

Because they have clear goals to meet, the students are encouraged to complete as many repetitions as necessary to reach stable, desired performance. A teacher-created checklist can be tailored to individual students' strengths. Some students may benefit from completing simple yes/no evaluations, while others may benefit from a more open-ended questionnaire that encourages deep, reflective thinking about particular elements of their performance.

Teachers should pay special attention to the development of desired habits. This focus is critical to the success of young musicians, because as students age, their ability to make major changes to learned skill sets decreases.[37] For example, if a student has spent seven years of public school music classes forming the same incorrect clarinet embouchure, changing that embouchure in the first year of collegiate study is much more difficult than changing the embouchure at the beginning of the sixth-grade year with a beginner whose embouchure has not yet stabilized.[38]

How students practice matters. Research has shown that students repeat what they see their teachers do instead of doing what their teachers say.[39] Expert teachers model what they want their students to do during face-to-face instruction.[40] Students may benefit from observing their teachers model deliberate practice activities. This includes watching teachers engage in setting appropriate goals, evaluating performance trials, making corrections, and completing correct repetitions. A deliberate practice exercise would be any activity that has a clear, attainable goal, where a learner completes a performance trial, the student receives formative feedback, and then completes another performance trial that either applies corrections or, if the first trial was correct, reinforces the desired outcome (see Table 1).

Train the Brain

The things people do change the structures of their brains. As students

TABLE 1

Sample Deliberate Practice Activities

Deliberate Practice Exercises	Band	Orchestra	Chorus
A clearly defined goal at an appropriate level of difficulty	Student can form the beginning flute embouchure.	Student can create a characteristic tone while playing a double stop.	Student can enunciate "let you" correctly.
What the student does	Complete the steps to form a flute embouchure and play several notes on the flute head joint.	Plays alternating down-bows and up-bows simultaneously on the D and A stings at a slow tempo.	Sings "let you" on a single pitch, moving the "t" closer to the "e" (rather than the "y").
Formative feedback	The student checks in a mirror for the "triangle of condensation" that shows if he or she is directing the air across the tone hole correctly.	The tone quality produced provides aural feedback.	The teacher compares and contrasts the student's "leh-choo" enunciation with the correct enunciation of "let you."
Opportunities for correction	If the "triangle of condensation" is not present, the student (with the assistance of the teacher) should review the steps to form a correct flute embouchure and try again.	If the tone is not characteristic, the student (with the teacher's guidance) will adjust the angle, placement, weight, and speed of the bow stroke to improve the tone.	If the diction is incorrect, the student (with the assistance of the teacher) continues to work on the proper placement of the "t" sound.
Opportunities for repetition	If the "triangle of condensation" is present, the student has formed the embouchure correctly and should repeat the exercise a number of times to solidify the learning. The student must check each time to make sure that he or she is still meeting the goal.	If the tone is characteristic, the student will complete several practice trials to ensure the bow stroke is secure and then continue to the next activity.	If the diction is correct, the student repeats the isolated phrase several times to cement the learning and then puts the phrase back into the context of the song.

practice, they complete many repetitions of desired actions. These repetitions cause the body to fire neural circuits many times. As the circuits fire repeatedly, synaptic connections are strengthened and glial cells apply myelin around axons in the brain to improve the speed, coordination, and ease of transmission of neural impulses. These changes in brain structure are the "under-the-hood" mechanisms that correlate with the observable increases in the performance quality of a musical motor skill.

Deliberate practice accounts for some of the variation among elite performers. Researchers may not agree on the sufficiency of deliberate practice to explain expert performance, but they agree that practice is necessary for people to maximize their abilities. By using structured practice activities, music educators can help their students develop the expertise needed to achieve their musical goals and reshape their brains in ways that support their musical success.

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