run-throughs was perfect or nearly so. This is a pretty stark difference, especially from two people who started out in the same place in terms of errors. It highlights the importance of isolating errors and reinforcing the correct way to play something.

Of the other pianists in the experiment, only three used some of these critical practice strategies, namely identifying the precise location of the error and making sure they did more correct repetitions than incorrect ones. Not surprisingly, these pianists were also among the top ranked.

This study is backed up by a large body of research on both athletes and musicians looking at the differences in how higher-performing individuals practice versus those who don't perform as well. For instance, in a classic experiment looking at high school varsity basketball players, researchers wanted to see how the highest-scoring players practiced differently from those who didn't do as well.[2] Throughout a practice session focused on free-throw shooting, the basketball players were asked different questions to try to probe what they were thinking about while practicing.

Before they started practicing, the experimenters asked the players, "Do you have a goal when practicing these free throws? If so, what is it?" If they said yes, they were asked, "What do you need to do to accomplish that goal?" If they missed two shots in a row, they were asked, "What do you need to do to make the next shot?" and "Why do you think you missed those last two shots?" After two successful free-throws in a row, they were asked, "Why do you think you made those last two shots?"[3]

Their answers to these questions illuminated how the high-scoring players and the lower-scoring players went about practicing differently. To the question about goals, the higher-scoring players gave much more specific answers, like "to make 10 out of 10 shots" or "to keep [my] eye on the rim of the basket," whereas the lower-scoring players would say something more general, like "to make baskets" or "to concentrate more." When asked about their strategies for accomplishing their goals or what they needed to do to make the next shot after they had missed a couple, the higher-scoring players again were much more specific. They said things like, "[I need to] keep my elbows in" or "focus on the back of the rim," whereas the lower-scoring players were again more vague, saying things like, "[I just need to do] my normal routine" or "focus."[4] When they missed shots, the higher-scoring players were also much more likely to attribute this to a specific issue with their technique, unlike the lower-scoring players, who were more likely to point to something general again, like lack of practice or lack of focus.

These results have been replicated many times in a variety of sports, in individuals at a variety of ages and ability levels. One study that looked at elite athletes competing at either the international or national level found that those who competed internationally were again much more likely to have specific goals, specific ways to achieve those goals, and specific reasons for their mistakes in the event of a failure.[5] This has also been found repeatedly in musicians across a variety of instruments. Researchers emphasize over and over that you cannot achieve a high level of performance by practicing mindlessly without specific goals and specific solutions.[6]

One of the leaders in this area of research, Dr. Barry Zimmerman, has put forth a three-step model for effective practice, which should be used in a constant cycle while practicing:[7]

Step 1: The Forethought Phase: Goal-Setting
Set specific goals for the practice session and choose specific practice strategies to achieve those goals.

Step 2: The Performance Phase: Self-Monitoring
Put the chosen strategies into practice and monitor closely how you're doing.

Step 3: Self-Reflection Phase
Evaluate how you did and precisely why things went well or didn't go well.

This model captures how the highest-performing musicians and athletes practice, and can be used by anyone, regardless of skill or years of experience.

Can effective practice skills be learned?

A frequent question about both musicians and athletes is whether their abilities are innate or acquired through practice. Maybe the people who are better at making specific goals, choosing specific strategies, and evaluating exactly why things didn't go well when they make mistakes are just better at those skills in the first place. And because they are better at those skills, they get better at their instrument or sport as a result.

Let's look at two studies that aimed to answer this question, one on athletes and one on musicians. In the study on athletes, researchers recruited college students who had never played basketball with the goal of helping them improve their free-throw shots.[8] Some of the students practiced free-throw shooting without any input on how to practice (the control group). The other students were taught about the three-part model developed by Dr. Zimmerman. Some of these students were only instructed in goal setting, some in both goal setting and self-monitoring while practicing, and some in all three parts (goal setting, self-monitoring, and self-reflection).

As you might guess, the groups who used the three-part model made much more improvement than the students who practiced however they wanted. Interestingly, the group that was only instructed in goal setting didn't do much better than the control group. The researchers also noted that the group who used the full three-step model focused the most on the process, rather than the outcome. And it was this focus on the *process* of improvement that allowed them to achieve more progress than the others.

This is a key point: focusing on the *process* will allow you to achieve a better outcome than only focusing on the outcome itself.

From this study it seems like teaching people to set specific goals, use specific practice strategies, monitor progress, and then reflect on exactly how things went seems to improve performance. It's a skill that can be learned.

But these were novice basketball players. What about more advanced musicians?

In an experiment looking at collegiate classical guitar students, the guitarists were given ten 20-minute practice sessions over about two weeks to learn a new piece of music.[9] Every practice session was video-recorded. After every other practice session, the guitarists performed whatever they had been working on (not necessarily the whole piece) as a way to measure their progress over the 10 practice sessions. After each of these "performances," everyone had to evaluate themselves. Half of the guitarists were shown the video of their performance before they did this self-evaluation.

In this study, the researchers were most interested in whether there was any change in the guitarists' ability to self-evaluate. The guitarists who watched their performance videos became much more precise and specific in their self-evaluations over the course of the experiment. Their comments became increasingly geared toward solving specific problems rather than more general comments about how satisfied (or not) they were with their playing. This focus on specific problem-solving goals was especially evident in the highest-performing guitarists, which further reinforces the other studies we've looked at.

It seems from these studies that this type of practicing—with a focus on specific goals, self-evaluation, and self-reflection—not only produces better performances, but is something that can be learned. Video-recording practice sessions and run-throughs and watching them with the intention of figuring out precisely what needs work is an especially helpful way to develop these skills. The benefit of video recording is reinforced by an interesting tidbit in another study that looked at different practicing strategies in pianists.[10] In that study, the top performing pianist was the only one who video recorded herself during practice and watched it back to assess how she was doing. Recording yourself and listening or watching back may be painful, but it's one of the most effective ways to improve.

Common practice mistakes and what to do instead

Now that we've discussed what good practicing looks like and why, let's return to some of those common bad practice habits I mentioned in Chapter 1 to look at what to do instead.

Common practicing mistake #1: Running through from beginning to end to start your practice session or starting from the beginning and stopping when you make a mistake (to either fix it or start over)

As you now know, simply playing through an entire song, piece, or movement is not practicing, it's just *playing*. You didn't set any specific goals before you started and as we've learned, this method will only solidify your mistakes, making them that much harder to fix later. "But how am I supposed to know what needs work if I don't run through it first?" you ask. My answer to that question is: if you were to do a run-through right now in front of your teacher, which spots would you worry about? That's where you should start. If your answer is, "I don't know," then you haven't been paying specific enough attention in your practicing up until now. Try recording yourself if you struggle with this. Even when a piece of music is brand new, you should have an idea of what's going to be hard for you based on past experience.

Try to be extremely specific about what needs work. Saying "everything sounds bad" is neither true nor helpful. It's critically important to be able to say very specifically, "The E on beat two of measure three is sharp" or "I'm rushing the 16th notes in beats three to four in bar 13," rather than just saying, "I'm out of tune" or "I'm rushing." It's only when you can be precise in this way that you can set specific goals and choose targeted strategies to address the issues that need attention.

In Chapter 1, I mentioned that there are two instances when running through is okay. The first is when a piece is brand new. On the *very first day* you start working on something, playing it through for the purpose of figuring out fingerings, bowings, where to breathe, and other fundamental matters of technique is fine. But in this case, you're not playing through from beginning to end. You're stopping to write in your fingerings, bowings, etc. While you're doing this, you should make a note of the sections you think will be the most difficult. Once you've finished putting in fingerings, etc., get right to work on those spots that you marked as the most challenging.

The other instance when running through is helpful is when you are getting ready to perform. Two to three weeks out from a performance (at least), your music should be completely learned so that you have time to practice performing (we'll discuss this more in Chapter 7 on interleaved practice). In that case, you *should* start each practice with a recorded run-through to assess how performance-ready you are. Your specific goal should be something along the lines of "Give a complete and compelling performance free from hesitations or stopping if I mess up" or "Concentrate all the way through and make all of my musical shapes and phrasing intentions convincing and clear." These are specific enough that you can evaluate exactly how you did afterward. Then listen to the recording of the run-through with your music to see whether you achieved your goals. Use your practice journal (which we'll talk about more in the final chapter) to write down everything that didn't go well, and then get to work on those spots.

Running through your piece should be a last step, never a first step. It may be months before you do your first full run-through. You shouldn't be running through the entire piece until you have solved all the problems and can play each section well. Then you have to work on joining the sections together. Once you've done that, now you're ready for a run-through. Often students feel they need to run through a piece repeatedly to "get a feel for it" or to "figure out how it goes." These were exactly the kinds of comments made by musicians in the studies we discussed at the beginning of the chapter who had the lowest rankings in terms of performance. These are too vague to be helpful goals or to direct you in using specific practice strategies.

If you do feel like you need to get a better feel for a piece before you can start to practice it, there are much more effective methods to accomplish this than running through. Listen to recordings, the more the better. Listen to see what different performers do in terms of timing, tempo, articulation, sound quality, vibrato, dynamics, phrasing, etc. Make notes of what you like and what you don't like. Again, be specific. When you hear something you like—or don't like—try to figure out *how* the performer is doing it.* Use mental practice to familiarize yourself with the piece (something we'll discuss in detail in Chapters 9 and 10). You can do an awful lot of work on phrasing, sound, expression, pacing, etc., before you even pick up your instrument. Study the score, particularly if it's something you will eventually play with other musicians. How does your part fit with the other part(s)? What's the structure of the piece? How do the different motives interact with each other? All this work can and should be done away from the instrument and will give you far more information than just playing it through repeatedly.

When you truly don't know where to start and everything seems to need an equal amount of work, the following two strategies can be very helpful:

1. Divide the piece into sections. Make sure these make musical sense—don't just do it by the line or the page. Look at each section and designate it as a Red, Yellow, or Green section. Red sections are the ones in the worst shape. These are your emergencies. Yellow sections are those that don't sound great, but aren't an emergency. Green sections sound fine. Maybe they're not perfect, but they're acceptable for now. Then start by working on your Red sections.
2. Work backward. Start from the final phrase (or final line, or final measure) and work on that until you're happy with it. Then back up a phrase/line/measure and work on that until you're happy with it. Put the two last phrases together to make sure you can go from one to the other smoothly. Keep working backward in this way until you're either

* I know many teachers discourage their students from listening to recordings of the piece they are working on for fear that the student will not develop their own interpretation. My opinion is that it depends on the level and sophistication of the student. Certainly, listening to only one recording over and over will be detrimental to developing a unique and flexible interpretation. But especially for undergraduates (and younger students), listening to the specific choices other artists have made in the pieces they are working on is a necessary part of their education to open their ears and imaginations to the possibilities that exist. To my mind, telling a student not to listen to recordings is akin to never demonstrating in a lesson. Students can't develop their interpretative skills if they have no models to draw from.

out of time or you make it to the beginning. This can help clarify which areas need work because doing it in reverse order will feel less familiar. When it's less familiar, your weak spots will be highlighted, which is exactly what you want in order to improve. You should be able to start literally anywhere in the piece and play it the way you want to. If your teacher has ever suggested starting from a certain measure and you've said, "Oh, I can't play it from there. I need to start the line before," this will be an especially valuable practice method for you.

Common practicing mistake #2: Putting on the metronome and playing through your piece slowly

I often hear students practice this way and I think they believe they are practicing well. After all, everyone is always saying to practice slowly, right? The purpose of practicing slowly is so you can feel and hear more clearly what the issues are, and so you can correct them with good form and technique. Going slowly helps you problem-solve more easily. But if you are just playing through big sections (or the whole piece) slowly, you're not accomplishing anything because there is no problem solving going on—you're just playing. Again, playing through is not practicing, it's just playing.

Maybe you think you're getting a feel for the piece this way and locking in good habits because you're going slowly and minimizing errors. But this is a very general goal and a very general practice strategy, not the kind of specific, targeted strategy that has been shown to work much better. Think of it this way: if you had to learn 100 vocabulary words in a second language, would it be effective to read each word and its translation, slowly one after the other, until you got through the whole list? Of course not. By the time you got to the end of the list, you'd probably remember maybe four words total—the first two and the last two, most likely. It would be much more effective to make flashcards and then divide them into three piles: words you already know, words that seem familiar (but you don't know), and words that are completely unfamiliar. Then, you would start studying the completely unfamiliar pile in small batches. The same thing is true with practicing: if you play through big sections slowly, you're going to retain next to nothing. Better to figure out where the hardest spots are (as described in the previous section) and get to work.

Common practicing mistake #3: Playing through your best spots over and over

It feels good to play well. We all like to play well. But the purpose of practicing is to improve your weaknesses. When you play music you can already play over and over again, you aren't accomplishing anything. What's your specific goal when you do this? As we've discussed, mistakes are necessary to learn. If you're not making mistakes, there's nothing to correct, and so nothing to learn. Leave the playing through of your best sections until the end, as a reward for all the hard work you did in the rest of your practice session.

Common practicing mistake #4: Doing mindless repetitions

Repetitions in and of themselves are not going to do anything. If you hear something that doesn't sound good and you play it over and over without stopping to figure out *why* it doesn't sound good and exactly how to fix it, all you are going to do is solidify the problem. You may be setting a specific goal (fix the shift in bar five) and using a specific strategy (do repetitions), but you aren't doing the self-reflection piece: *why* are you failing to nail that shift each time? Every time you play something, it should take you closer and closer to your goal. If you are making the same mistake in the same way each time, you haven't identified clearly or precisely enough what is causing that mistake. Take a step back and try as many different things as you can come up with to solve the problem. If nothing works, make a note to talk to your teacher about it.

Here is another tidbit from one of the studies on practice strategies: in a study with volleyball players, the highest performing athletes were much more likely to say they would seek out help from their coach when they missed their serves repeatedly.[11] I think students are often scared to tell their teachers that they are struggling with something, but it's literally our job as teachers to help you solve the problems you can't solve on your own. The very best lessons are the ones where students come in with a list of things they need help with, rather than trying to hide their weaknesses from me as their teacher.

Nobody likes making mistakes. They're frustrating, especially when we want to just *play*. But they're necessary and inevitable. The difference between great players and merely good players is how those great players *respond* to their mistakes. Having specific goals, specific strategies, and precise self-reflection makes all the difference.

But what if there were a way to make mistakes *on purpose* to speed up learning? That's the topic of our next chapter.

3

Use Errors to Your Advantage

Samantha arrived for her first lesson with me and I noticed immediately that her bow hold was getting in her way. Her pinky and thumb were straight—rather than curved, with springy flexibility—and her hand was contorted at an awkward angle. We worked hard in that lesson to start fixing her bow hold, and she seemed like an attentive and diligent student, so I was hopeful that she would be able to correct the problems relatively quickly. When she left that day, it was already looking better.

The next week when she arrived, I asked how her practicing had gone.

"Good, I think . . . ?" she told me with a shrug.

She started to play, but her bow hold looked exactly the same as the week before. No improvement.

"So, do you remember that last week in your lesson, we talked a lot about your bow hold?" I asked her.

"Yeah."

"Did you work on that at home this week?"

"Um . . . I didn't really think about it that much, actually."

Okay, I thought, she doesn't know how to work on it. No wonder! So I proceeded to talk to her about good practice techniques.

The next week, it was the same issue. And the week after that. And the week after that. In fact, after a whole year, nothing much had changed. When I reminded her to pay attention to her bow hold, she could do it just fine. But she never seemed to hold it correctly without my prompting. I was a relatively new teacher at the time, and I was frustrated by her lack of progress. Did she just not care? Or was she not really paying attention? Or maybe I just wasn't explaining it clearly enough.

It turns out, it was none of these things.

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Why bad habits are so persistent

In many ways, the brain is a prediction machine. When there is a mismatch between what you predict and what actually happens, your brain registers that discrepancy. In fact, something that comes as a surprise causes a larger reaction in the brain than when everything goes according to plan.[1] We also learn more quickly when we are surprised by something than when our predictions are correct. Think about the experience of playing loudly in a rest because the conductor takes more time than you expected. You only need to do that once to make sure you are looking up at the conductor at that spot so you don't fall into the same trap twice.

It's the same when we are practicing: our brains register the mistake *if we are aware we've made one*. If we don't do anything to try to change that mistake, that's when the wrong pathway starts to get reinforced, as we discussed in the first chapter. But what if you don't even realize you've made an error? Or what if you don't realize you have a bad habit, you just know things aren't working? How can you fix something you're not even aware of?

Enter two powerful techniques for getting rid of bad habits: amplification of error and old way/new way.

Before we discuss either of these methods, though, we need to understand why bad habits are so hard to correct beyond the fact that they are well-myelinated pathways (as discussed in Chapter 1). The inventor of old way/new way is Harry Lyndon, a teacher who worked in Australia. He explained that something called "proactive inhibition" is trying to protect the bad habit from going away.[2] Proactive inhibition—or interference, as it is most commonly known these days—is a well-documented phenomenon in the brain where old knowledge can prevent us from learning new knowledge if that new knowledge conflicts with the old knowledge. For instance, if you were erroneously taught that an F major scale has no sharps or flats, just like C major, it will be hard to remember to play a B-flat in the F major scale. The new knowledge (F major has one flat) conflicts with the old knowledge (F major has no sharps or flats), even though that old knowledge is incorrect.

The old knowledge actually makes us forget the new knowledge more quickly that we normally would. We have no control over this—it's just a feature of how the brain works. When it comes to bad habits, the teacher can clearly see the issue, but the student can't really feel the problem because they are so used to playing that way. This is exactly what was going on with Samantha and her bow hold: it was simply outside of her conscious awareness, even though I had pointed it out repeatedly and it was very obvious to me as her teacher. Some people have much higher levels of proactive interference than others, which makes it even harder for them to correct bad habits. So part of the reason bad habits are so stubborn is that our brains are *protecting* them. And since they are outside of our conscious awareness, we do them automatically without realizing it, even if they have been pointed out repeatedly.

Harry Lyndon reasoned that if you could bring the bad habit into conscious awareness, then you could override the proactive interference and correct the bad habit. This principle of bringing automatic habits back into conscious awareness is why amplification of error and old way/new way work so well.

Amplification of error

Now that you understand this, let's discuss amplification of error first. I should note that both methods we'll discuss ideally require you to have a (good) teacher to help you through this process.*

In amplification of error, the teacher should identify the main cause of the bad habit. There may be many different reasons for the bad habit, but you want to try to identify the primary issue that's causing other elements of the bad habit. As an example, maybe a viola player's left wrist is bent too much so the heel of the hand is touching the neck of the instrument, as shown in Figure 3.1b. This is known as a "pizza wrist" to many violin and viola teachers. Often, a pizza wrist is caused by the instrument being unstable on the player's shoulder, so they are trying to hold it in place more securely with the hand and wrist. A pizza wrist will help secure the instrument, but it won't allow you to play very well. In this case, the primary issue is the security of the instrument on the shoulder, not the wrist itself.

Once you've identified the main error, the next step is to exaggerate the error. In the example of the pizza wrist, maybe the violin doesn't feel secure on the player's shoulder because they are pushing their shoulder up and

* If you are trying to correct bad habits on your own without a teacher to help guide you, I would encourage you to watch many videos of great players to see the exact physical motions they make. Then video yourself from many different angles until you can pinpoint the precise differences between how you play and how great musicians play. Even better, though: take a lesson with someone, even if it's just a single session over the internet. That could save you hundreds of hours of frustration.

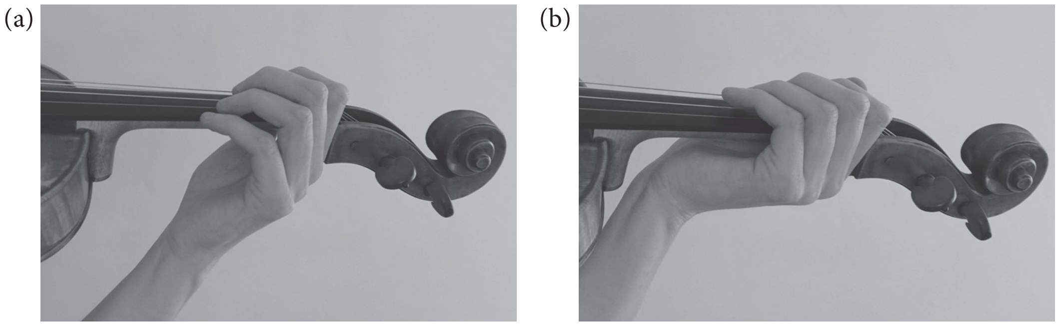

Figure 3.1 a. Proper left-hand shape. b. Incorrect left-hand shape, known as a "pizza wrist."

forward. In that case, the player should push it up and forward even more. By exaggerating the bad habit, it makes the student more aware of it, and then they can feel more clearly why it's a problem. In one study looking at this teaching method in golfers, researchers found that a group of golfers who were taught to exaggerate their bad habit self-corrected the issue without their coach having to get involved. In contrast, the group who were given explicit instruction on the correct way to hit the ball showed the same lack of improvement as the control group who weren't given any feedback at all.[3]

This all comes with an important caveat, however. When someone's initial skill level is relatively high, amplifying the error seems to work quite well to help correct the issue. But when someone's skill level is lower, they already have so much variability in what they are doing, amplifying the error can make things worse. In that case, what's known as "haptic guidance"—helping show someone what it feels like to do it correctly—is more helpful. This is what parents do when they hold the back of a kid's bike who is learning to ride without training wheels for the first time, or when a dad stands behind his daughter learning to swing a baseball bat and puts his hands over her hands, guiding her in how to swing.[4] So if you're already pretty skilled at something and you're trying to refine that skill, amplifying the error can help you figure out a better solution. But if you have a lower skill level, amplifying the error can be like flailing around randomly—it probably won't help that much.

Old way/new way

The second technique, old way/new way, is also designed to rapidly correct a bad habit by bringing it into conscious awareness. Again, this is best done under the guidance of a good teacher. Amazingly, old way/new way works so well that in a *single session* people can go from doing something correctly 0% of the time to doing it correctly at least 80% of the time. Even better, this change seems to be permanent.

Before we get into the steps for old way/new way, I should mention that all the steps are necessary—so, no cutting corners—and the student must be motivated to change their bad habit.

With those preconditions met, here's how it works:

Step 1: The student and the teacher should gather video evidence of the bad habit in action, as well as video of the good habit, performed by either the student themself, the teacher, or another professional. They should watch these videos together to make sure the student can clearly see the difference between the old way (the bad habit) and the new way (the good habit they are trying to learn). The student should describe the differences between the two as clearly as they can. They may need the teacher's help for this, which is why this step should be done together.

Step 2: The student should perform the action the old way, doing their bad habit on purpose. They should then describe in as much detail as possible what the old habit feels like. This may take a while because what the student is feeling may be pretty vague at first. But it's critically important that they can describe clearly and concretely what it feels like because this will bring the habit back into conscious awareness. Again, the teacher likely needs to help with this step. (It may also help for the student to close their eyes to feel what they are doing more clearly.) Like the error amplification method described above, this step should focus on the primary error that is causing other issues. Once the student can describe the old way clearly, they need to repeat the old way several times to make sure they can do it on purpose reliably. Again, the point of this step is to bring the old way into conscious awareness.

Step 3: The student needs to figure out how to do the new way (the new habit they are trying to learn). Again, they will probably need the teacher's help for this. Once the student can do the new way correctly, they should describe what it feels like in as much detail as possible. Like describing the old way, this also needs to be as concrete as possible.

Step 4: The student then alternates between the old way and the new way. They should do the old way and describe in detail what it feels like. Then they should do the new way and describe what that feels like. Go back and forth between the old way and the new way like this five times. Even though it can be a bit annoying, it's extremely important not to skip the step of describing what it feels like each time because the verbal descriptions are what bring the habit back into conscious awareness.

Step 5: Do only the new way several times (studies on this method have differing numbers of repetitions of the new way, but most do six repetitions).

And that's it. The error should be corrected. No need to repeat this process at the next lesson or the next day as a review.

The studies that have looked at this method in athletes have some very encouraging results. One study looked at two Olympic athletes—a javelin thrower and a sprinter—who were clearly great athletes, but they both had stubborn bad habits that were having a negative effect on their ability in competitions.[5] For the javelin thrower, the day after the old way/new way intervention, she did 100% of her throws correctly in practice and continued to throw accurately in the weeks following. The sprinter had similar results. And in competition, both athletes performed correctly 85%–90% of the time. The numbers in Figure 3.2 speak for themselves.

Another study looked at a swimmer who did an old way/new way intervention only three days (!) before the national championships.[6] That may seem risky, but it paid off for the swimmer. Before doing old way/new way, he started races—diving into the water and then starting to swim—incorrectly about half the time, both in practice and in competition. This really cost him time. Again, the numbers in Figure 3.3 speak for themselves, but look especially at the percentage of correct starts in the national championships: 85% of the starts were correct in an extremely high-pressure situation just *three days* after making the change. Anyone who has ever tried to correct a bad habit the usual way will appreciate how amazing that is.

		Before Old Way/New Way		After Old Way/New Way	
		Incorrect Tries	Correct Tries	Incorrect Tries	Correct Tries
Javelin thrower	Practice	90%	10%	15%–20%	80%–85%
	Competition	100%	0%	10%	90%
Sprinter	Practice	100%	0%	13%	87%
	Competition	100%	0%	15%	85%

Figure 3.2 Percentage of incorrect and correct tries for each athlete before and after the old way/new way intervention.

Before Old Way/New Way		
	Incorrect Tries	*Correct Tries*
Practice	60%	40%
Competition	50%	50%
After Old Way/New Way		
	Incorrect Tries	*Correct Tries*
Practice 2 days later	0%	100%
Nationals 3 days later	15%	85%
Practice 2 weeks later	17%	83%
World Championships 1 month later	0%	100%
Practice 8 months later	6%	94%

Figure 3.3 Percentage of incorrect and correct tries before the old way/new way intervention compared to after the intervention in a variety of different events.

This approach has also been used in vocational training—people learning to be hairdressers or carpenters or plumbers—with great success.[7] In an experiment using old way/new way in these kinds of settings, researchers compared the traditional way of getting rid of an old habit—the teacher shows the student the right way and has them do many repetitions—with old way/new way. At the beginning of the study, all the students were doing the skill incorrectly 100% of the time. After the different training methods, the old way/new way students were getting it right up to 94% of the time. In contrast, the students corrected in the traditional way were able to do the new way, at best, 35.9% of the time. Figure 3.4 shows a graphic representation of these statistics.

Old way/new way seems to have additional benefits beyond just technical correction: in a study looking at this method with a tennis player, researchers also measured the effect this intervention had on psychological skills, namely anxiety control, concentration, self-confidence, and motivation.[8] They found that in addition to fixing the tennis player's bad habit, all the psychological measures improved as well, as shown in Figure 3.5. These sorts of psychological skills are obviously of critical importance in performing well, so any method that can correct a long-ingrained bad habit and can also improve psychological performance skills is well worth trying.

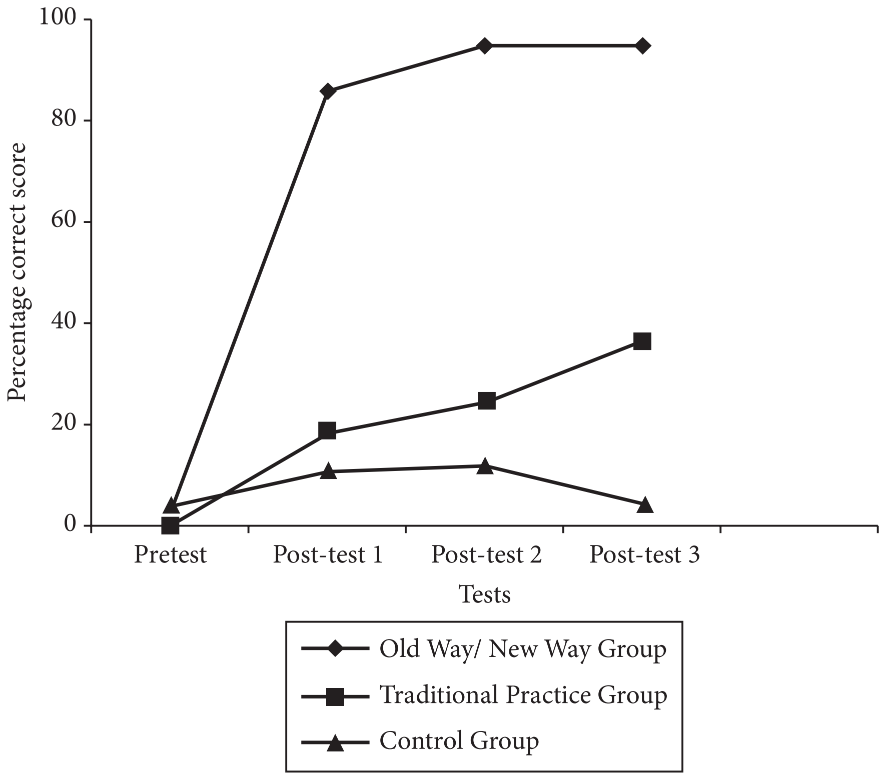

Figure 3.4 Performance of each group on a series of three skills tests given after the old way/new way intervention.

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	Before Old Way/New Way	After Old Way/New Way
Anxiety Control	13%	58%
Concentration	29%	63%
Self-confidence	50%	86%
Motivation	64%	89%

Figure 3.5 The athlete's scores (out of a possible 100%) on each psychological measure, both before and after the old way/new way intervention.

Although most of these studies were done with a small number of participants, the fact that the results were replicated across a wide variety of sports and skills gives confidence that this method works. From my own teaching, I can attest to the effectiveness of old way/new way. No longer do my students persist in their bad habits for weeks and months as they used to.

The role of feedback

Both methods of error correction described in this chapter serve to bring detrimental habits into conscious awareness so the student can self-correct. This aligns well with other research on the best *time* for teachers to give feedback to students. Students who are given immediate feedback do far worse in performance tests than students who are asked to self-evaluate before receiving feedback.[9] It seems that when students are given immediate feedback, they are not allowed to develop their own error detection abilities, and instead rely solely on the feedback of their teacher.[10]

This is directly related to the common advice of practicing in front of a mirror. Often string players and singers in particular are told to do this in order to become more aware of what they are doing. This can be beneficial at first, but it doesn't solve the problem long-term. The most obvious example of this for string players is learning to play with a straight bow (keeping the bow parallel to the bridge). This is a difficult skill to learn for two reasons: on violin and viola, when you move your arm in what feels like a straight line, the bow will go crooked relative to the bridge; plus, what looks straight from the player's perspective often is an optical illusion caused by the curvature of the bridge and the fingerboard.

Violinists and violists are commonly told to practice in front of a mirror to straighten out their bow. Many of us (myself included) spend years and years practicing in front of a mirror to no avail. We can play with a perfectly straight bow when we are looking in the mirror, but as soon as we are without that feedback—like in a lesson or concert—we can't keep our bows straight. The reason is that the mirror prevents us from forming a clear kinesthetic image of what a straight bow *feels* like—we are unable to tell by feel if our bows are straight when we don't have the visual feedback of the mirror. In this case, a much better way to work on straight bow is to video yourself playing a short passage—and don't look at the screen while playing—while trying to keep a straight bow. Then watch it back to see how you did. You will be able to match your memory of what it felt like to what you see on the video, which is much more beneficial in helping develop the kinesthetic awareness of what a straight bow feels like. This principle can be applied to anything you would normally practice in front of a mirror. The mirror is a great tool to get started, but then the simultaneous feedback needs to be removed so you can develop a clear sense of what something feels like when it's correct. A mirror will hinder you in that pursuit.

I had many more students like Samantha over the years, with bad habits that just didn't seem to go away despite my (and their) best efforts. Now I use old way/new way and amplification of error instead, and I can vouch for their effectiveness. Old way/new way usually takes an entire hour-long lesson, but it seems to me to be a good use of time, especially compared to how long it used to take—months or years or sometimes never! Learning about these techniques strongly reinforced for me the power of errors in learning. Rather than being scared of mistakes and trying to avoid them at all costs, we can harness our errors to work for us rather than against us if we are strategic in how we use them.

SECTION II
USING YOUR TIME WELL

As musicians, we are always looking for ways to maximize our time in the practice room, to learn faster and more efficiently. In this section, we'll look at what the research has to say about how to best utilize our time for maximum benefit by discussing the importance of taking breaks, the power of interleaved practice, and the benefits of including variability in your practice sessions.

4
The Fastest Way to Learn Music: Take More Breaks

When I started giving presentations on the neuroscience of practicing, people often approached me afterward to ask a variant of the same question. It would go something like: "So once, I got really sick a few weeks before my recital and I had to stop practicing for a whole week. When I started practicing again, I could play my music *better* and more easily than before I was sick, even though I hadn't practiced for a whole week. What's that about?" Or: "Once I tried to learn how to double tongue and I could not do it at all, so I just gave up. But then I tried again a few months later and it was really easy. How did that happen?"

Most of us have had strange experiences like this that seem too good to be true. Despite that, taking breaks on purpose as a practice strategy just seems wildly irresponsible. After all, if you're not practicing, you're not improving. Right?

Maybe not.

The power of breaks

One of the most common misconceptions about practicing (especially in classical music) is that it's necessary to practice many hours every day, tackling everything all at once for as much time as possible, and to practice each individual piece, passage, or skill for a long time before moving on to something else. It's not unusual for students in top music schools to practice six to eight hours a day (or more) and for students to believe this is required to become a "serious" musician. These same students often practice for two to three hours (or more) at a time without a break (or with only minimal breaks). And it's common for students to get fixated on one section or passage for an hour or more at a time. Students are using their time in this way

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because they believe—or have been told by their teachers—that this sort of punishing schedule is the only way to succeed.

It's not.

In fact, research going back to the 1880s shows that this sort of schedule is the *least* effective for learning something both quickly and durably. Yes, this schedule will eventually lead to improvement and performance success, but there's a *much* easier, much less time-consuming way that works significantly better. Taking breaks is one of the most powerful practice strategies we have. It sounds too good to be true, but it's not. It's a general principle of how all living things learn.

Take more breaks and learn faster.

To understand what's going on here, we need to start with a German psychologist by the name of Hermann Ebbinghaus. He is credited with discovering the power of breaks, something researchers now call spaced practice. He published his findings in 1885 in a book entitled *Über das Gedächtnis. Untersuchungen zur experimentellen Psychologie* (published in English as *Memory: A Contribution to Experimental Psychology*), and his discoveries have continued to be studied and tested ever since.[1] Today, it is well established and universally accepted by scientists that taking breaks is more effective than doing one big block of practicing all at once. Unfortunately, this counterintuitive idea has not made it into mainstream culture or the culture of music practicing.

There are countless studies that have found that spacing out practice sessions by taking breaks is the most effective way to learn. Much of the research examines how people study for academic tests. But more recently, researchers have extended this question to tasks requiring a combination of complex motor and cognitive skills, like playing music. The best studies looking at the power of breaks when it comes to combining these skills were done with surgeons. If you think about it, surgical skills provide a good parallel to musical skills: surgeons are required to learn extremely precise, challenging motor skills that are performed in high-pressure, cognitively demanding situations. What has been found in surgeons can therefore be applied to musicians. Let's take a trip to medical school to see what we can learn.

In one experiment, medical students were divided into two groups to learn a set of surgical skills. The first group practiced these skills for three hours straight without a break, something known as massed practice.[2] I'll call this group Team Massed. A second group practiced for 40 minutes and then took a 20-minute walk. I'll call them Team Breaks. When they came back, they practiced for another 40 minutes and then took another 20-minute walk. After their second walk, they practiced once more for 40 minutes. Note that Team Breaks only practiced for two hours total, a full hour less than Team Massed. However, when they were tested at the end of the training, Team Breaks did significantly better. Not only did Team Breaks get to take two nice walks, they practiced for a full hour less than Team Massed, and yet they did better on the skills test.

Interesting for sure. But there's more.

In another study, researchers focused on how surgical skills taught in the lab transfer to real-life situations.[3] Again, there were two groups. In this case, Team Massed did four training sessions all in one day for a total of five and a half hours of training. Team Breaks had one training session per week for four consecutive weeks (every Monday for a month, for instance) until they had also done a total of five and a half hours of training.

Like the first experiment we discussed, Team Breaks did better when tested on their skills. But they also vastly outperformed Team Massed when it came to transferring the skills to a more real-life situation. In fact, for some of the skills, Team Massed scored the same on the transfer test as they had on the pretest before they had done any training at all. That's not good! They made literally no measurable improvement that transferred after five and a half hours of practice! In contrast, Team Breaks did significantly better in the real-life transfer situation versus their score on the pretest.

This is critical information for us as musicians. When our skills transfer to new situations more effectively, we save time because we don't have to work on those basic skills in every new context. We hope that what we learn in one context (scales, etudes, etc.) will be there for us in a piece of music so we can focus more on the *music* and less on the technical aspects of what we're playing. We also don't want to feel like we have to start each new piece from zero. Hopefully the skills we just acquired working on that last concerto will transfer to our new sonata movement, for instance.

So far, we've seen that medical students who spend less time practicing and take walks instead perform better in the end, and we've seen that practicing something just once a week—versus five and a half hours all at once—results in better transfer to other situations, also saving time. But an important question to ask is whether this applies at different skill levels. Maybe the absolute skill level of both groups isn't very high. Maybe the spaced groups are doing better, but overall nobody is very good at the skills they're learning. As musicians, we want our practicing to be effective, but we also want to play at the highest level possible. The idea of taking breaks is only worth doing if you're not going to sacrifice quality, and maybe long practice sessions are what it takes to reach that level of ability. It's a good question, and it's relevant to surgeons, too. After all, you want your surgeon to be highly competent and precise!

To look at this question, a team of researchers decided to measure the percentage of students who reached *proficiency* on a given surgical task.[4] That's a much higher bar. Again, there were two groups of students. In this study, Team Massed had three blocks of training all in one day, back-to-back. Each training session was 75 minutes long. Team Breaks also had three total training blocks of 75 minutes each, but they had one training per week for three weeks (e.g., every Monday for three weeks).

In the end, the differences between the groups were astounding—and worrisome if massed practice is the way surgeons are typically trained. On one skill, only 11% (!) of Team Massed reached proficiency, while 70% of Team Breaks reached proficiency. On another skill, only 39% of Team Massed reached proficiency, compared to 90% of Team Breaks. In fact, for every skill tested, Team Breaks did significantly better by at least 33 percentage points or more, as shown in Figure 4.1.

So far, spaced practice is looking pretty good: higher skill level in less time with better transfer. But what about how long it sticks with you? That's important, too, if you are trying to maximize your time. Intuitively, we're aware that cramming doesn't work well to remember something long-term. Think about those all-night cram sessions before an exam: you might remember just enough to get through the exam, but if someone asks you about that material a year later (sometimes even a week later!) you can't remember any of it. But maybe it's just because you were studying in the middle of the night and

	Team Massed % at proficiency	Team Breaks % at proficiency
Elastic band	39%	90%
Pipe cleaner	11%	70%
Beads	11%	50%
Cutting circle	22%	60%
Suturing	22%	55%

Figure 4.1 The percentage of surgical students who reached proficiency in each group after training on each skill.

you were tired; maybe it has nothing to do with spacing out your studying over a longer period of time.

An experiment on mice shows otherwise.*

In this experiment, the mice were trained to run through a maze.[5] In this case, Team Massed trained for an hour all at once. In contrast, Team Breaks trained for 15 minutes at a time with an hour break in between each training session until they had also done an hour total. By the end of the training, both groups of mice were doing great at the maze. None of the mice received any additional training, but each day, they were tested to see how well they could remember the maze. After 15 days, Team Massed were basically back to where they started—they had forgotten how to run the maze. In contrast, Team Breaks could still remember how to run the maze 60 days later! Again, both groups got the same amount of training, but Team Breaks remembered how to run the maze for significantly longer.

Here's what we've learned so far: when we take more breaks between practice sessions, we perform better, our skills transfer better to new situations, we reach a much higher level of proficiency, and we remember what we learned for far longer. It seems like magic, doesn't it? Now the question is *why*: why does taking breaks work so much better? To answer this question, we need to look at what is happening inside the brain.

What happens in the brain during breaks?

In the summer of 2021, a fascinating study came out that captured the attention of the scientific community.[6] It looked at brain activity during so-called microbreaks. In this experiment, researchers asked people to learn a key-press sequence on a computer keyboard. The goal was to perform this sequence as quickly and accurately as possible. Participants were given 10 seconds to practice, followed by a 10-second microbreak, during which they just sat and did nothing. They continued through multiple rounds of this while the experimenters measured not only their performance but also their brain activity.

Amazingly, researchers found that the majority of the performance improvements happened during the *breaks*. You can see this in Figure 4.2. In

* I know mice aren't humans, but spaced practice is a basic principle of how all living things learn most effectively, so it's worth looking at what this research can teach us.

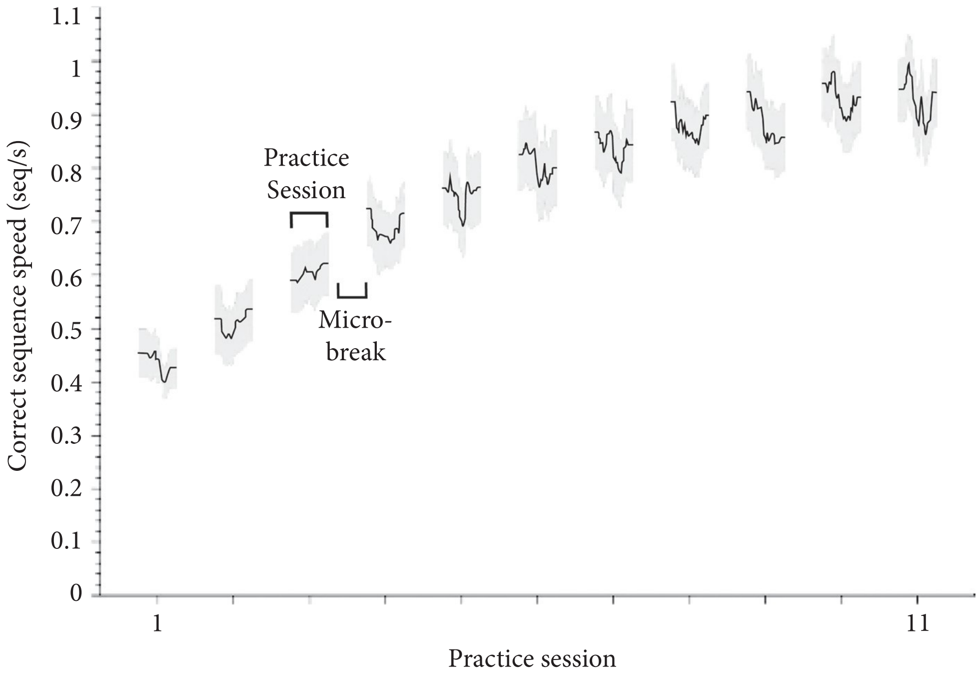

Figure 4.2 Performance while practicing interspersed with microbreaks, from practice session #1 (left side) to practice session #11 (right side).

Modified from Buch, E., et al. (2021). Consolidation of human skill linked to waking hippocampo-neocortical replay. *Cell Reports*. 35(10): 109193. © Elsevier 2021.

this graph, the little squiggles show the participants' performance while they were practicing. The spaces between the squiggles are the breaks. The left side of the graph shows the first practice session, progressing to the final practice session on the right. You can see that after each break, the participants performed at a higher level than at the end of the previous practice session. More interestingly, the researchers discovered that during the breaks, the brain replayed the key-press sequence 20 times faster (and backward). The brain was continuing to practice in a super fast-forward manner while participants were taking their breaks.

The implications of this study are enormously important. Breaks aren't wasted time: they are the *most important time* for skill improvement.

Based on this research, I now do my repetitions a bit differently than I used to (as discussed in Chapter 1). I used to do all my correct repetitions—say, five times in a row—in one block without a break. Now I do three correct repetitions in a row, take a 10–15 second break, and then do three more in a row. The same rules apply (discussed in Chapter 1) about going back to zero if you mess up and trying to achieve at least 50% overlearning. There are just breaks built in now. I find that I can solidify my work faster this way and it sticks with me better over time (like those mice in the maze).

Is anything else going on in the brain when we take breaks?

Long-term potentiation

In Chapter 1, we touched on the idea of long-term potentiation (LTP), the process by which synapses strengthen themselves when you learn something new. Long-term potentiation essentially makes it easier for the neurons involved to talk to each other, facilitated by structural changes to the synapse. It's a little bit like upgrading your modem and the speed of your wifi: when you have faster internet speed and better equipment, it is much easier to communicate during a video call because it doesn't freeze or distort every two seconds.

Long-term potentiation is the first step in learning something new or improving. Scientists study what happens to neurons undergoing LTP to understand what may be happening in the initial stages of learning. Researchers can simulate LTP in the lab by zapping a neuronal ensemble with an electrical pulse, which mimics the electrical signal that travels down the axon, discussed in Chapter 1. Scientists have found that when you activate a neuronal ensemble in this way, some of the neurons undergo LTP, but not all of them.[7] If you zap them again 10 minutes later, nothing happens—no more neurons undergo LTP. But if you wait for an hour and give them another zap, then many more neurons undergo LTP. In fact, you double the amount of LTP by waiting an hour.

Why? Why wait for an hour?

As mentioned earlier, LTP involves structural changes at the synapse to make communication between neurons easier. Those structural changes require building materials. If those materials are sitting there waiting, the neuron can take advantage of the electrical stimulation right away and undergo LTP. But if the building materials aren't there, the neuron needs time to move them to the cell wall. Researchers have found that apparently an hour is the amount of time needed. If another round of electrical stimulation is given 10 minutes (or even 30 minutes) after the first one, it won't do anything—the building materials aren't there yet. Think of it like a construction site that is waiting on more wood and paint to arrive: telling the construction site to hurry up won't do any good. The wood and paint have a commute that takes an hour, and so everybody just has to wait.

Since LTP is the first step in learning something new, once neurons have made this change, they are at a higher level of readiness for further practicing or studying. Because neurons that have undergone LTP can communicate more easily, the skill supported by those neurons will feel easier. Scientists think this is one of the mechanisms underlying the efficacy of spaced practice. But can't you just keep practicing that same skill during the hour that the neurons are moving the building materials to the cell wall rather than taking a break? Unfortunately, no. The brain doesn't start doing any necessary construction (or reconstruction) while you are actively using the neurons involved. Consider a city road as an analogy: during significant construction, workers need to shut down the road for paving and other improvements. You can't have cars driving on the road while it's being fixed. The same thing is true for your brain: it can only do the necessary construction when you are taking a break.

What does this mean for practicing?

In practical terms, this research means that particularly when you are working on something new, practice it for a little bit and then leave it. Come back to that passage later in the day and work on it a bit more. Then leave it alone and come back to it once more at the end of the day. But don't overdo it—from the study on LTP we were just discussing, it seems that three times is enough: additional rounds of stimulation after the third had no effect.

What should you do during your break?

Should you abstain from all practicing during the break, or is it okay to practice different music while you're taking a break from one passage? After all, it's not very practical for most musicians to work on one small passage and then stop practicing completely for an hour or two—we just have too much music to learn. A group of researchers realized the same thing was true of students learning surgical skills: they have very intensive training schedules and need to learn many different skills quickly. In an experiment designed to test this, there were five different groups:[8]

- Team Massed practiced without breaks
- Team Similar practiced a very similar skill during the break

- Team Different practiced a very different skill during the break
- Team Observation observed expert surgeons performing the skill they were learning during the break
- Team Break took an actual break and did nothing.

At the end of the experiment, all the groups were tested on the skill they had practiced. As I'm sure you can guess, Team Massed did the worst. Team Similar did just as badly. Interestingly, Team Different did as well as Team Break. In fact, the final three groups—Team Different, Team Observation, and Team Break—all did about the same. Therefore, as long as you are practicing something that's different enough, you can continue to practice during your break from the first passage you were working on. As an example, if you were working on a fast, flashy passage and now you're taking a break from that, maybe working on something slow and lyrical would be a good contrast for your brain. For multi-instrumentalists or percussionists who play many different instruments, switching to a different instrument for a while would also be a good way to take a break and let your brain do the necessary reconstruction.

Retroactive interference

In addition to the brain activity during breaks that we've already discussed, the brain also appears to do more large-scale reorganization during the breaks, especially when something is brand new. When we start learning something new, an area of the brain called the prefrontal cortex is heavily involved. This area of the brain, right behind your forehead, is typically involved at the early stages of learning when the new skill feels effortful and we aren't very good at it yet. The new skill usually feels unstable as well. In one study looking at brain activation for a new skill versus that skill after a break, researchers found that when participants practiced a skill for the first time, the prefrontal cortex was indeed highly active. But when the participants returned five and a half hours later for a second practice session, the prefrontal cortex was no longer activated.[9] This time, it was areas further back in the brain that were activated: the premotor area, the parietal lobe, and the cerebellum. These areas are associated with more stable storage of the skill, meaning it will feel easier and more automatic.

This longer-term reorganization is related to something called *retroactive interference*, which is also mitigated by taking breaks. In Chapter 3, we discussed something called *proactive* interference, which is when old knowledge makes it much harder to learn something new (as in the case of bad habits). *Retroactive* interference is the opposite: new knowledge hampers the performance of old knowledge.

Confused? I don't blame you. And also, how can you ever learn anything if the interference goes both ways?

Retroactive interference is typically only seen under special conditions: if you learn two brand new things back-to-back that are very similar, the second one will get in the way of the first one, making the first one harder to remember or perform. In this case the "old" knowledge isn't actually old, it's just what you learned first when you learned two brand new things. Let's clarify this with a musical example. Let's say you are a kid learning Bach's *Minuet in G* for the first time. The main melody has two different endings, as shown in Figure 4.3. If you work on Ending A and then work on Ending B immediately after, you're going to have a harder time playing Ending A when you come back to it the next day. The two versions are quite similar to each other, and you learned them back-to-back, so they interfere with each other.

According to research, you can avoid this problem by waiting approximately six hours in between practicing Ending A and Ending B. When you take a break of about six hours, this retroactive interference effect disappears, presumably because your brain has time to strengthen Ending A during the break.[10] When material is brand new to the brain, it's fragile and easily disrupted. But when you take a break, this new skill gets strengthened, and so it's less susceptible to interference later. I like to think of new knowledge like a little baby animal that was just born. It's so fragile and small and it needs protection. Breaks provide protection, giving new knowledge a little bit of armor and making it less vulnerable. But again, retroactive interference only seems to show up for things that are very similar to each other. You don't have to worry about this interference happening if you learn the opening to a brand

Figure 4.3 Music for *Minuet in G* (attributed to J.S. Bach) with the two different endings indicated.

new Romantic-era concerto, followed by a brand-new Bach Allemande. This material is very different, so it is not likely to trigger retroactive interference in the brain.

Our brains are doing a lot when we're taking a break. Rather than being wasted time when we should be practicing, breaks are critical if we want to learn effectively and improve as quickly as possible. So far, we've only looked at what's going on in the brain during short breaks within one day. What about those surgical studies where they took a week off in between practice sessions? Or musicians who take a week off by accident and suddenly can play much better once they come back? What's the brain doing over longer breaks?

To answer these questions, we need to talk about the role of sleep, the biggest and most important break of all.

5
Can You Learn Music in Your Sleep?

If you're like most people—and especially most conservatory students—you probably think sleep is a waste of time. Given the choice between practicing more or getting enough sleep, I think most musicians would choose practicing. Or at least that's what they feel they have to do. There just aren't enough hours in the day to get everything done, so sleep is the first thing to go. I mean, do you really need to spend eight hours out of every day lying in bed doing nothing? It seems so unproductive . . . .

However, sleep is critical for learning, and the influence of sleep—and sleep deprivation—on learning is astounding. I know it's hard to get enough sleep, especially when you're in school, but I hope by the end of this chapter you'll reconsider your sleep-deprived lifestyle. If you prioritize sleep, you will be more productive and retain more of what you've practiced. Suddenly, you'll realize you have more time each day: when you're well rested, you can get everything done in a lot less time.

The magic of sleep

To begin our discussion on the importance of sleep, I'd like to introduce you to the work of Dr. Matthew Walker, one of the leading neuroscientists on the study of sleep. He has done research on sleep and learning for decades, and his findings are directly applicable to musicians. In a series of studies from the early 2000s, Dr. Walker asked research participants to perform a button-press sequence as quickly and accurately as possible. His control group (Group 1) practiced 12 times (the initial training) and then were retested every four hours for the rest of the day.[1] Think of these retests as mini performances. Not surprisingly, as the participants practiced, they got a little better every time in a linear way that the scientists could predict. They also got a little better at each mini performance, again in a linear way that was predictable. No surprises there—this was just to demonstrate that people

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continue to get better as they practice and that repeated performances within a day continue this predictable trend.

What *was* surprising were the results the next day, when the participants returned after a full night's sleep. Suddenly they performed the tasks much faster and more accurately than the day before. This also wasn't a linear increase, it was a huge jump, as you can see in Figure 5.1. In these graphs, the black bars show performance on Day 1, whereas the white bars show performance on Day 2. The top graph shows speed, the bottom graph shows number of mistakes. There is a clear jump in performance (faster with fewer mistakes) on Day 2, following a night of sleep.

To probe this surprising finding, a second group of people (Group 2) also completed the initial 12 training trials, but they didn't have any mini performances at all until Day 2. Despite less practice on Day 1, they also showed a huge jump in performance on Day 2. Group 2's first mini performance was at a significantly higher level than at the end of training on Day 1 and far outpaced Group 1's first mini performance.

But maybe it has nothing to do sleep per se, maybe it's just the passage of time that matters. In the last chapter, we saw several different examples of how the brain continues to work during breaks, resulting in better performance after the break. Maybe for the effect Dr. Walker found, 12 hours has to pass and sleep has nothing to do with it.

To test this, Dr. Walker recruited two new groups of people (Groups 3 and 4). Group 3 practiced first at 10 am, followed by a retest at 10 pm. There was some improvement, but not a huge jump, even though 12 hours had passed. However, at the second retest at 10 am the next day, the participants *did* show a large boost in performance; they were faster and more accurate following a night of sleep. Group 4, on the other hand, had their first practice at 10 pm followed by a retest the next day at 10 am. This is also a 12-hour window of time, but critically, these 12 hours include a night of sleep. If sleep is what matters—and not just the mere passage of time—Group 4 would be expected to show the large jump in performance at their first retest the next day. In fact, this is exactly what was found. Further, Group 4's second retest at 10 pm on Day 2 showed some improvement, but again not that much. In both Groups 3 and 4, the jump in performance only happened following a night of sleep.

Figure 5.2 shows these findings. As in Figure 5.1, the black bars are performance on Day 1, whereas the white bars are performance on Day 2. The top graphs show speed, whereas the bottom ones show number of mistakes. The graphs on the left show Group 3, the graphs on the right show Group 4.

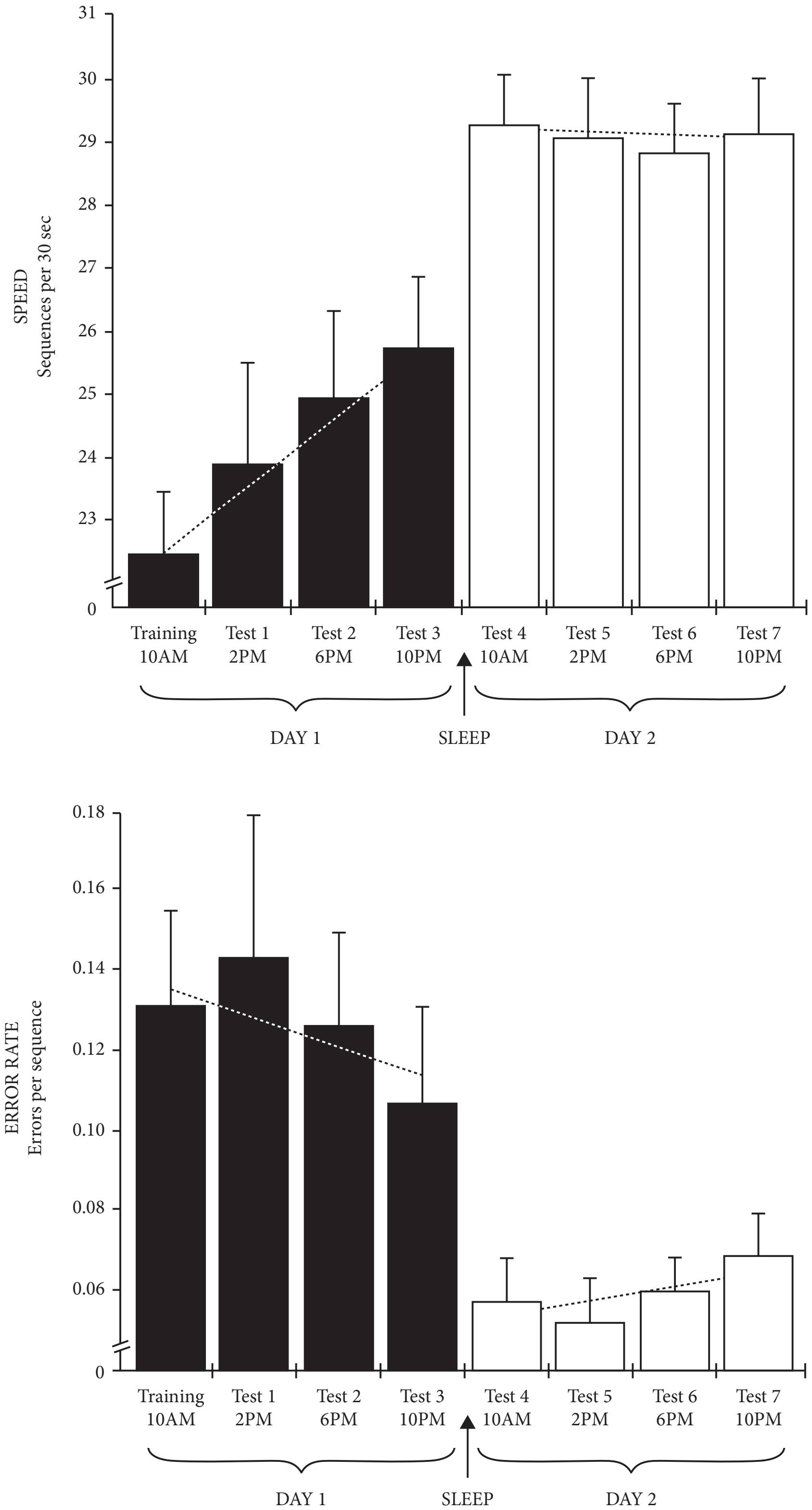

Figure 5.1 Graphs showing performance on Day 1 (black bars) versus Day 2 (white bars) for both speed (top) and number of mistakes (bottom).

Reproduced with permission from Walker, M., et al. (2002). Practice with sleep makes perfect: Sleep-dependent motor skill learning. *Neuron.* 35(1): 205–211.

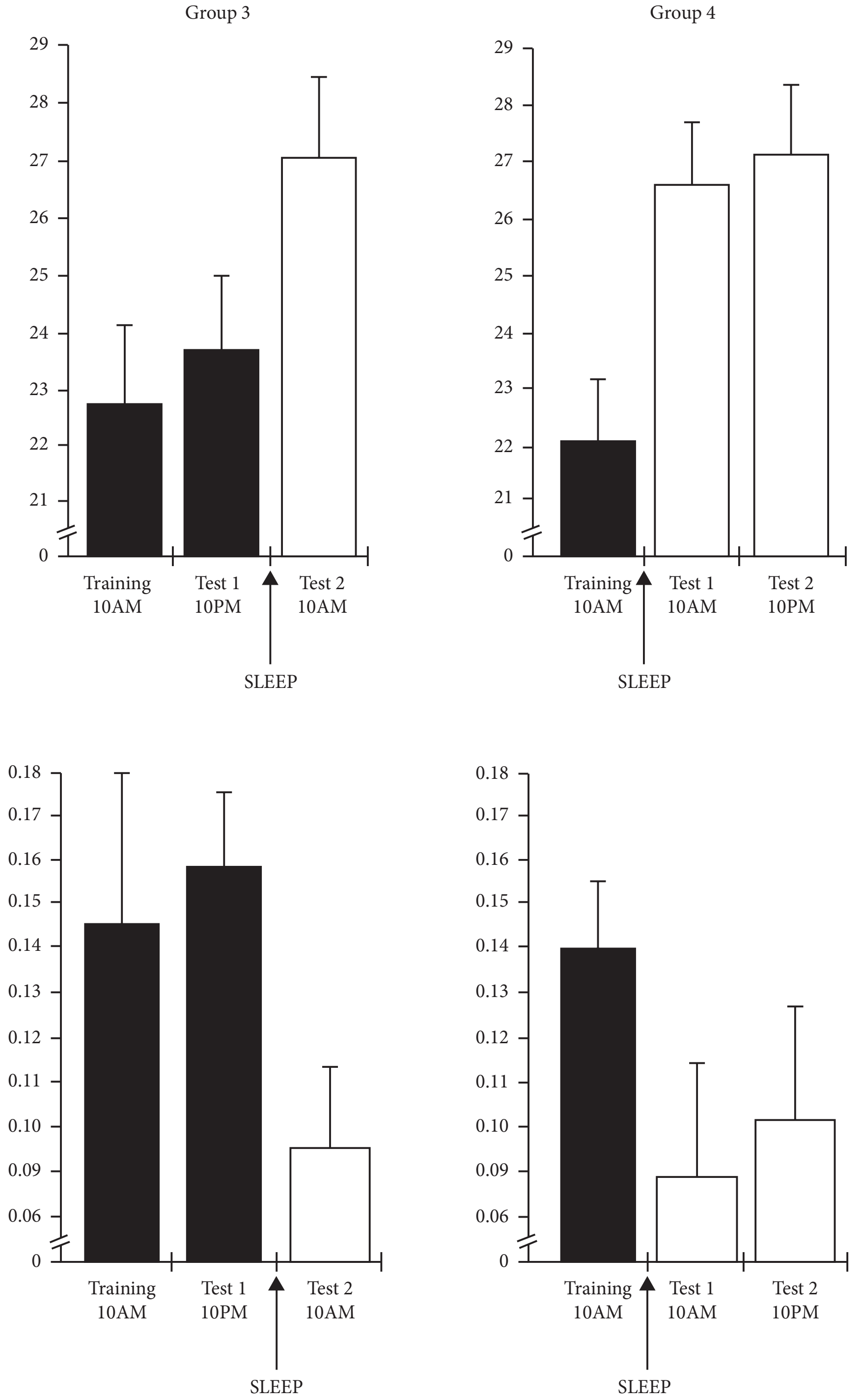

Figure 5.2 Graphs showing the performance of Groups 3 and 4, and the role of sleep in boosting performance.

Reproduced with permission from Walker, M., et al. (2002). Practice with sleep makes perfect: sleep-dependent motor skill learning. *Neuron.* 35(1): 205–211.

Notice that the jump in performance always follows a night of sleep and is not merely due to the simple passage of time.

In fact, all the different parameters tested showed the same thing: practice within a day yields minor increases in ability, whereas after a full night of sleep, there is a significant jump in ability, both in terms of speed and accuracy. One group was even assigned double training—so they practiced 24 times instead of just 12—but that didn't seem to make much difference in ability over the course of the day.[2] In fact, the group with double training was no more accurate at the end of the day than the people who practiced half as much. And their overnight improvement was essentially the same as the other groups. They spent twice as much time for no measurable gain! In a nutshell, this research shows that if you practice far less and get a full night's sleep, you will suddenly be *much* better the next day without any additional effort.

Hopefully you are starting to see the critical role of sleep in making the best use of your time. But again, the question is *why*. What happens when we're asleep to produce this amazing result?

To answer this question, Dr. Walker and his colleagues asked participants to sleep over in the lab to monitor their sleep. Through this monitoring, they found there was a strong correlation between the amount of improvement people made the next day and the amount of time they spent in something called Stage 2 NREM sleep in the fourth quarter of the night. Let's break down what that means.

Many people have heard of REM sleep (rapid eye movement sleep)—that's when we are dreaming and our eyes are moving quickly behind our eyelids. The opposite of REM sleep is non-REM sleep, or NREM sleep.

Sleep scientists also divide sleep into four different stages to describe how deeply someone is sleeping. Stage 1 sleep is very light sleep when it's easy to wake someone up. At the other extreme, stage 4 sleep is very deep sleep—the kind of sleep that causes you to sleep through your alarm. Stage 2 sleep, therefore, is on the lighter side, but not the lightest kind of sleep.

Lastly, sleep scientists consider a full night's sleep for adults to be eight hours on average. This is divided into four quarters of approximately two hours each, so the fourth quarter is the final two hours in an eight-hour night of sleep.

To reiterate, the amount of improvement seen the next day is strongly correlated with the amount of time people spend in Stage 2 NREM sleep in the fourth quarter of the night. But again: WHY? What's so special about Stage 2 NREM sleep in the fourth quarter of the night? Plus, this is a correlation. Scientists are always quick to point out that correlation is not causation: just because two things are related, you can't necessarily say one causes the other. However, based on other sleep research, we know there is a special kind of brain activity—called sleep spindles—which peaks during Stage 2 sleep, particularly in the fourth quarter of the night. Sleep spindles cause changes at the synapse, and in Chapter 1 we discussed the fact that changes at the synapse are necessary for learning. Scientists also know that for motor tasks that are not terribly complex, NREM sleep appears to be critical for consolidating, strengthening, and stabilizing a new skill. Basically, the more time people spend in Stage 2 NREM sleep in the fourth quarter of the night, the more opportunity their brains have to make the necessary changes that support learning. This is thought to be the reason behind the major performance improvements the next day.

A reasonable question at this juncture is whether anyone has looked at this in musicians or in people learning complex, real-world skills generally. As it turns out, there *was* a study done on musicians to answer this question. In this experiment, nonpianist musicians had to learn a short two-bar melody at the keyboard (shown in Figure 5.3). Just like the people Dr. Walker tested, musicians made small gains during the day as they continued to practice, but after a night's sleep they got a significant boost in their performance.[3] To make sure it was sleep that was making the difference, the researchers tested a variety of groups, all with different practice and sleep schedules. In every case, the jump in performance ability was only seen after a full night of sleep. This is also backed up by an experiment that used the video game *DanceStage* for PlayStation 2 to test complex motor skill learning. Researchers found the same thing: the boost in performance ability only happened following a night of sleep.[4]

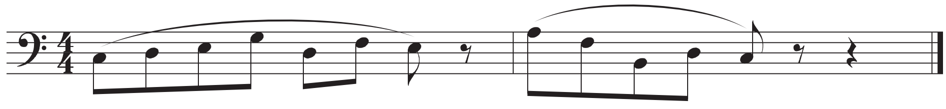

Figure 5.3 The short two-bar melody participants learned at the piano.