Interpreting and Applying Research-Based Learning Strategies for Musical Practice

by

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A Research Paper Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Musical Arts

Approved April 2024 by the
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ARIZONA STATE UNIVERSITY

May 2024

ABSTRACT

The practice strategies that musicians employ can be made more effective by leveraging existing research about memory and learning. Musicians often use strategies that feel intuitive, such as massed practice and rote repetition, but that research has proven ineffective. When they do employ strategies that are effective, such as varied practice and chunking, they often do not understand the reasons why they are effective and therefore cannot use the principles behind effective learning to generate new approaches when faced with an unfamiliar challenge or learning plateau.

In this paper, I propose that, through developing knowledge of the research surrounding learning and memory, musicians can acquire insight into the learning process and develop the ability to self-generate effective practice strategies that address issues specific to their own practice. As a result, they can avoid common learning pitfalls and gain greater confidence in their ability to approach learning complicated skills and taking on big projects. This paper examines and distills recent research of effective learning into an in-depth and practical document for use by musicians. Additionally, this document interprets and applies existing research-based learning strategies—such as retrieval practice, spaced repetition, varied practice, interleaved practice, and chunking—to musical practice through the lens of contemporary percussion repertoire. Readers of this work will develop an in-depth understanding of memory and learning and be able to apply that information practically and immediately in their own practice.

ACKNOWLEDGMENTS

I'd like to thank Dr. Michael Compitello for his guidance and support while I was working on this research paper and studying at Arizona State University these last three years. My writing has improved immensely throughout the process of working on this paper, and the finished project would have been diminished without his help.

Additionally, I'd like to thank Dr. Gabriel Bolaños and Dr. Andrew Campbell for their guidance as members of my committee. I am glad to have worked with them while preparing for my comprehensive exams and in preparing this paper.

I'm also extremely grateful for the support I have received from my family, friends, and partner during the last three years and throughout my entire educational career. My family has supported me throughout the entirety of my education. My peers in the percussion studio have also served as inspirations and collaborators and I am glad to have had the privilege to work with them in the last few years. Finally, I could not do any of this without my partner, Haley Gillia, who has supported me throughout it all.

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CHAPTER 1

INTRODUCTION

Overview

In this paper, I provide an overview of several concepts that contribute to effective learning, including deliberate practice, the development of high-quality mental representations, the various stages of memory involved in learning, and the implementation of desirable difficulties. Additionally, I describe a variety of strategies and techniques which leverage these concepts for musical practice such as retrieval practice, spaced repetition, interleaved practice, varied practice, and chunking. Discussion of each strategy includes explanation of the strategy and the research that supports it as well as suggestions for practical applications to musical practice, supported by specific musical examples drawn from my own repertoire. In the final part of the document, I provide two extended case studies to offer an in-depth application of multiple strategies in conjunction with one another.

Background

This document is born out of my interest in applying research-based learning strategies to musical practice. My interest was first sparked early in my musical education by the conflict between the amount of effort and time I felt I could devote to practicing each day and what my environment seemed to encourage. In my undergraduate degree, I was surrounded by hard-working peers who would practice for incredible amounts of time each day, sacrificing their sleep and working to the point of exhaustion. A single-minded focus on the quantity of practice above all else was encouraged in the way teachers and students alike spoke about practicing. It appeared that succeeding in music meant practicing for six to eight hours a day at the expense of all other areas of life. I tried to develop discipline and motivation to practice in this way, both to match my peers' efforts and my teachers' goals but was never able to sustain my focus. I could sustain about three to four hours of daily practice and found that over time sacrificing my sleep diminished the quality and effectiveness of these practice hours. I felt frustration and shame at my inability to match the effort of my peers as it seemed that I clearly did not care enough and that I simply lacked what it takes to succeed as a musician.

My interest was further sparked by the frustration I felt whenever I ran into musical or technical issues with which my teachers were unable to help. I felt that teachers often communicated goals that encompassed *what* I should do and *why* I should do it but were less helpful in providing strategies that allowed me to accomplish those goals quickly, effectively, and consistently. In a lesson, a teacher might provide a strategy to address a particular issue, but if I was unable to solve the issue using their preferred strategy, I was lost. The inability to accomplish a given goal made me feel as if I just was not trying hard enough or that there was some fundamental lack of musicianship on my part.

I developed the suspicion that there must be better ways to practice and sought ways to improve the three to four hours of daily practice that I knew I could sustain. Initially, I explored general productivity and time-management strategies, which improved my ability to handle multiple projects and balance practicing with other activities in my life. However, my understanding of effective learning took a significant turn when I discovered the book *Make It Stick: The Science of Successful Learning* by Brown, Roediger, and McDaniel, which would become a cornerstone of my research.

Additionally, I encountered the concept of deliberate practice through the work of Anders Ericsson, particularly through his book *Peak*. Despite the valuable insights gained from these sources, I found them lacking in specificity and immediate applicability to musical practice. Upon starting my doctoral studies, I recognized an opportunity to further study the science behind effective learning and consolidate the best of this knowledge into a practical resource tailored for musicians.

Existing Literature and Contribution

There are a variety of research studies that test the application of learning strategies such as retrieval practice, spaced repetition, interleaved practice, varied practice, and chunking to a variety of different activities, including math, language learning, sports, and music. The bulk of this research has been conducted in the last 70 to 80 years. Although these strategies have long been proven effective, practitioners have been slow to adopt them. This is likely because research studies are not always conducted with the goal of practical application in mind.

In the last 20 years, however, there has been a concerted effort to communicate the principles of effective learning to a wider audience. These sources, such as Anders Ericsson's *Peak* and Brown, Roediger, and McDaniel's *Make It Stick*, explain the principles behind effective learning in an accessible manner without sacrificing scientific rigor. However, these sources write about these concepts and strategies in a general sense and do not provide specific applications, limiting their immediate usefulness for musicians.

In the last 10 years, the topic of research-based learning has become increasingly popular in musical circles as musicians encounter the research and books mentioned above. As a result, musicians have started to take it upon themselves to interpret and apply this knowledge to musical practice. There has been a steady rise of writings and podcasts that describe the application of research-based learning strategies to musical practice such as the websites of timpanist Jason Haaheim and violist Molly Gebrian as well as Julliard faculty member Noa Kageyama's website and podcast *The Bulletproof Musician.* Musicians have begun to write their own books that draw upon this research, such as Christopher Berg's *Practicing Music by Design* and Lois Svard's *The Musical Brain*.

Each of these sources presents valuable information about the research and its relation to musical practice, but few of them provide practical applications of the strategies using specific examples. Through reading these sources, I felt my knowledge of effective learning improve, but I sometimes did not know how to apply the strategies beyond in a general way or to specific musical situations while practicing. I believed that there needed to be a source with an approach that primarily focused on application, supported by specific musical examples, to fill in the details on how to interpret and apply these strategies for practical use.

Goal and Approach

The goal of my research was to create a document that explains the principles behind effective learning and the use of specific strategies, supported by specific musical examples, in a way that musicians could easily understand and apply to their practice. I did not want to simply restate the concepts or reaffirm that the strategies are scientifically sound, which I believe is effectively accomplished by existing literature. Instead, my approach was separated into three steps: (1) surveying the existing literature surrounding effective learning drawing upon a variety of sources, (2) interpreting and explaining these strategies and concepts and making their relevance to musical practice clear, and (3) suggest practical applications of the strategies to musical practice, supported by specific musical examples drawn from my own repertoire.

Challenges and Limitations

One challenge I encountered in researching and writing this document was choosing which concepts and strategies to include. As I became more immersed in the subject, it became increasingly apparent that there are so many interconnected factors that contribute to effective learning and as a result it became difficult to explain anything without feeling the need to explain everything. I wished to keep the document centered on application and this meant I had to make conscious decisions about what to include and not to include. I made these decisions based on what I deemed to be most essential or the most readily applicable. As such, the contents of the document are influenced by what I personally find to be the most relevant for musical practice.

Another challenge was due to the intended specificity of the document. Although these strategies are proven effective, the exact application of them to musical practice relies on intuition and interpretation. For example, it is easy to test the effects of interleaved practice and spaced practice in a general sense, but harder to test the degree to which practice should be interleaved or spaced. The exact effects of a very specific use of any strategy on future learning are difficult to know. As such, many of the specific applications of strategies are the product of my own interpretation and are based on what I have found successful. Other practitioners may interpret and apply these concepts and strategies in different ways.

Finally, it was difficult to transmit this information in a written format and decide on an organizational structure for the document. Although the principles behind effective learning are interconnected, they are not necessarily meant to be understood in a linear way. The structure of the document is a result of what I found to be the most effective way of communicating these ideas, but an ideal document would be a living resource that can be updated incrementally over time.

CHAPTER 2

LAYING THE GROUNDWORK FOR EFFECTIVE LEARNING: DELIBERATE PRACTICE, MENTAL REPRESENTATIONS, STAGES OF MEMORY, AND DESIRABLE DIFFICULTIES

Deliberate Practice

The term *deliberate practice* was first introduced in a 1993 literature review led by Swedish psychologist Anders Ericsson titled “The Role of Deliberate Practice in the Acquisition of Expert Performance.” Ericsson and his coauthors researched the acquisition of expert level performance across a variety of domains, including music. Through their review, they found that experience and practice alone do not guarantee maximal performance. Instead, a great number of hours of a very specific type of practice, that they term deliberate practice, was necessary to attain expert level performance in any given activity—such as music, sports, or games.[1]

Ericsson defines deliberate practice as a specific sort of practice that involves effective training activities that have been designed by a highly qualified teacher or coach to maximize improvement between meetings with the teacher.[2] Due to some confusion around the definition of deliberate practice, Ericsson would later codify deliberate practice as practice that adheres to four criteria: (1) the trainee must receive individualized training from a well-qualified teacher, (2) a clear goal must be articulated

[1] K. Anders Ericsson, Ralf Th. Krampe, and Clemens Tesch-Römer. “The Role of Deliberate Practice in Expert Skill Acquisition,” *Psychology Review* 100, no. 3 (2019): 367-368.

[2] Ericsson, Krampe, and Tesch-Römer. “The Role of Deliberate Practice in Expert Skill Acquisition,” 368.

by the teacher and the student must be able to internally represent that goal, (3) the teacher must design a practice activity that the student can use to attain the identified goal and allows for immediate feedback between attempts, and (4) the trainee must be able to repeat revised attempts that gradually approach the desired performance goal.[3]

The first criterion of deliberate practice is that it involves "individualized training for a trainee by a well-qualified teacher" who can "assess which aspects a particular training would be able to improve in the time until the next meeting and is able to recommend practice strategies with established effectiveness."[4] For musicians, these meetings are the individual lessons that students have with their teacher. A musician's teacher can ideally listen to a student, assess aspects of their technique and musical expression, and design practice activities for the student to use in their practice time before their next lesson.

The second criterion is that the teacher must be able to articulate the goal to be achieved by the student and the student must be able to "internally represent this goal during practice."[5] This means that the teacher must describe the goal in a way that the student can understand so that they conceptualize that goal in their mind and accurately assess whether they are making progress towards the goal. Ericsson writes that it is

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[3] K. Anders Ericsson and Karl W. Harwell, "Deliberate Practice and Proposed Limits on the Effects of Practice on the Acquisition of Expert Performance: Why the Original Definition Matters and Recommendations for Future Research," *Frontiers in Psychology* 10 (2019): 2396, https://doi.org/10.3389/fpsyg.2019.02396.
[4] Ericsson and Harwell.
[5] Ericsson and Harwell.

"challenging for trainees to be able to mentally represent a goal for a level of performance that the trainee is initially unable to attain."[6]

The third criterion is that the teacher must design a practice activity that can be used to "attain the identified goal for performance" and that the activity "allows the trainee to get immediate feedback on a given attempt."[7] This means that the teacher must not only explain what the goal is or why the goal is important; they must also explain a practice activity that can effectively teach the student *how* to accomplish the goal. The activity also must allow the student to get "immediate feedback on a given attempt."[8] In other words, the activity must allow the student the ability to differentiate between successful and unsuccessful attempts.

The final criterion of deliberate practice is that "the trainee is able to make repeated revised attempts that gradually approach the desired goal performance."[9] This means that there must be time for the student to repeatedly engage in the activity and refine their attempts. If the activity does not involve reflecting on feedback and continually revising attempts or does not give the trainee the time to do so, then the practice is not deliberate.

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[6] Ericsson and Harwell.
[7] Ericsson and Harwell.
[8] Ericsson and Harwell.
[9] Ericsson and Harwell.

Other Types of Practice

It is important to note that the authors' definition of deliberate practice relies heavily on instruction from teachers and coaches. However, because many training activities associated with performance gain in a skill do not necessarily meet all the criteria of deliberate practice, Ericsson later introduced terms for two other types of practice: *naïve practice* and *purposeful practice.* [10]

Naïve practice is practice of a task where the learner engages in the task repeatedly and expects that repetition alone will improve their performance.[11] Playing a piece from beginning to end multiple times without setting specific goals is an example of naïve practice. Naïve practice is practice without well-defined and specific goals, and it is frequently seen in younger and inexperienced learners or when learners are faced with a new challenge for which their existing strategies have not prepared them.

Purposeful practice adheres to many of the same principles of deliberate practice such as having well-defined and specific goals, focusing deeply on the task at hand, incorporating feedback throughout the practice process, and pushing the learner just beyond their comfort zone or current level of ability.[12] To Ericsson, the main distinction between purposeful practice and deliberate practice is that purposeful practice does not

[10] Ericsson and Harwell.
[11] K. Anders Ericsson, and Robert Pool, *Peak: Secrets from the New Science of Expertise* (Houghton Mifflin Harcourt, 2016), 14.
[12] K. Anders Ericsson, and Robert Pool, *Peak,* 15.

include regular meetings with a highly qualified teacher who can diagnose problems and assign practice activities to address them.[13]

I make the following distinctions between the three types of practice: naïve practice occurs when a learner is not quite sure what to practice or how to do it, purposeful practice is when the learner knows what must be done, but may not know the best way of doing it, and deliberate practice is when a learner knows both what to do and an effective strategy to accomplish it. Most of an advanced musician's practice time is spent either in purposeful practice or deliberate practice.

Limits of Deliberate Practice

Deliberate practice is excellent as a general guide for practicing and musicians should aspire to follow the general principles of deliberate practice as closely as they can, setting clear and specific goals, using practice strategies with proven effectiveness, ensuring that they receive feedback regularly (both via self-reflection and by playing for others), and making repeated revised attempts to move towards specific goals. However, the definition of deliberate practice does not provide details about what specific types of strategies are effective and why, besides that they are usually communicated to a student by a teacher. As such, performers should be made aware of specific research-based concepts and strategies to utilize in their deliberate practice.

[13] Ericsson concedes that as a learner becomes more skilled, their practice is likely reasonably effective even without regular meetings with a teacher, although Ericsson would still categorize this as purposeful practice and not deliberate practice.

Mental Representations

Another crucial element of skill acquisition is the development of *mental representations* that encompass the skill. Ericsson defines a mental representation as a "mental structure that corresponds to an object, an idea, a collection of information, or anything else, concrete or abstract, that the brain is thinking about."[14] These mental representations encompass both the physical and conceptual aspects of skill acquisition in any domain.

In music, mental representations include how a performer thinks about their technique, how they might interpret a given piece, how they believe certain styles or genres of music should be played, how they relate their previous performance experiences to upcoming performances, and so on. In short, musicians form mental representations encompassing all the different possible aspects of music making. As learners become more skilled and experienced, those mental representations become more specific, nuanced, complicated, hierarchical, interconnected, and comprehensive. For instance, a beginning musician's mental representation of a major scale may include the specific collection of pitches that make up each major scale and the idea that a major scale sounds "happy." An expert's mental representation will include more complexity, detail, and abstraction, such as knowledge of the specific pattern of whole steps and half steps that make up a major scale, how a major scale operates in opposition to other modes, and a more complex understanding of how a specific scale can affect the musical or emotive character of a piece.

[14] Ericsson and Pool. *Peak*, 58.

The research surrounding mental representations has shown that experts develop more structured and hierarchical mental representations of a given task than novices.[15] In a study that targeted the differences between the mental representations in high-skill and novice tennis players for a tennis serve, the authors found that the mental representations of experts were organized in a "distinctive tree-like hierarchical structure" and that the mental representations between individuals were similar and matched well with the demands of the task. In contrast, novices' mental representations lacked hierarchical structures, had much more variability between individuals, and were not as well suited to the task.[16] For instance, experts tend to classify the different movements that make up a tennis serve according to their function whereas novices rely more on surface level perceptual features.[17]

Ericsson writes that even when the skill being practiced is primarily physical, mental representations are still a major factor in that skill's development. Using a competitive diver learning a new dive as an example, he writes that "much of the practice is devoted to forming a clear mental picture of what the dive should look like at every moment" and "more importantly, what it should feel like in terms of body position and momentum."[18] As a skill is practiced, mental representations are refined and improved to guide future attempts at the skill. Ericsson writes that expert performers are set apart from

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[15] Cornelia Frank, William M. Land, and Thomas Schack, "Mental Representation and Learning: The Influence of Practice on the Development of Mental Representation Structure in Complex Action," *Psychology of Sport and Exercise* 14 (2013): 354.
[16] Thomas Schack, and Franz Mechsner, "Representation of Motor Skills in Human Long-Term Memory," *Neuroscience Letters 391 (2006):* 77.
[17] Schack and Mechsner, 78.
[18] Ericsson and Pool, 60.

everyone else because of the "quality and quantity of their mental representations" which allow them to "make faster, more accurate decisions, and respond more quickly and effectively" in any given situation.[19]

Therefore, musicians should consciously reflect and elaborate on their mental representations throughout the practicing process. By developing complex and nuanced mental representations, musicians will be able to identify, assess, and solve problems while practicing. Mental representations allow musicians to develop the ability to critically think about the music they are playing and monitor every aspect involved in music making.

Stages of Memory

Musicians frequently believe that memorization is a process separate from learning, but pianist and neuroscientist Lois Svard claims that memory and learning are linked. Svard defines learning as "the process by which new information is encoded in the brain" and defines memory as "the encoding of the information itself."[20] In other words, learning is the act of acquiring new knowledge or a skill whereas memory is the ability to store and retrieve that information.[21] To understand why certain strategies are effective for learning, musicians should be aware of the various stages of memory. Svard articulates five stages of memory relevant to musicians: encoding, consolidation, storage, retrieval, and reconsolidation.[22]

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[19] Ericsson and Pool, 62.
[20] Lois Svard, *The Musical Brain: What Students, Teachers, and Performers Need to Know* (New York: Oxford University Press, 2023), 88.
[21] Gregory Zlotnik and Alexander Vansintjan, "Memory: An Extended Definition," *Frontiers in Psychology* 10 (2019): 2523, https://doi.org/10.3389/fpsyg.2019.02523.
[22] Svard, 88.

Encoding is the process of committing new information and skills to memory. Brown, Roediger, and McDaniel describe encoding as the brain converting sensory perceptions into "chemical and electrical changes that form a mental representation of the patterns…. observed."[23] For musicians, encoding occurs when first encountering a new piece of music or when working on adding more detail to music already known. Musicians who learn from notated music encode when they translate that notation into the resulting physical movements and sounds. As a skill is practiced or new knowledge is learned, the brain creates "meaningful neural representations" that connect sensory areas of the brain with the motor areas "necessary to make the movements to produce the sound."[24] These neural representations are referred to as *memory traces.*[25] It is important to note that mental representations and the neural representations formed by practice are separate concepts. To Ericsson, mental representations are cognitive structures that serve as ways of structuring thoughts and concepts around an idea or skill whereas the representations involved with memory traces refer to specific changes in the brain that occur due to encoding new information.

After material is encoded, the encoded material must be committed to long-term memory through a process called consolidation.[26] Consolidation happens as material becomes more comfortable more through practice and repetition. As learning is consolidated, the learner notices details and connections missed in earlier practice

[23] Peter C. Brown, Henry L. Roediger, and Mark A. McDaniel, *Make It Stick: The Science of Successful Learning* (Cambridge: Belknap Press of Harvard University Press, 2014), 72.
[24] Svard, 88.
[25] Brown, Roediger, and McDaniel, 72.
[26] Brown, Roedieger, and McDaniel, *Make It Stick*, 73.

sessions, corrects errors, and refines muscular movements. Mental representations become more comprehensive, and memory traces are strengthened. During consolidation, the learner connects new information with existing knowledge.

After a learned skill is consolidated, it is then stored in long-term memory during the storage phase. Critically, information cannot be stored if it was not "focused on in the encoding and consolidation process."[27] This suggests that while practicing, learners should actively pay attention to all the various sensory details they are experiencing as reflecting on and concretely describing the details of what is being practiced (such as articulations, phrase markings, dynamics, physical motions) will help in the encoding, consolidation, and storage of that skill or knowledge. Musicians can improve the quality of their learning by seeking out connections between what they are practicing and their existing mental representations. For example, if a musician identifies that all the pitches in a particular problematic passage are fragments of a specific scale or that the passage is almost the same as another they learned previously in the piece, that information will assist in the storage of the knowledge and skill. As such, analysis can be a powerful practice tool for musicians. A study conducted by Roger Chaffin and Gabriella Imreh found that developing a strong conceptual memory of a piece of music—by examining form, structure, and other musical details—assists in strengthening performance and retrieval. They write that understanding the structure of a piece is particularly helpful for differentiating between similar material. [28]

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[27] Svard, *The Musical Brain*, 89.

[28] Roger Chaffin and Gabriella Imreh, "Practicing Perfection: Piano Performance as Expert Memory," *Psychological Science* 13, no. 4 (2002): 343.

During retrieval, the brain accesses memories that have been encoded, consolidated, and stored in the previous stages, and as such is relied upon most by musicians during performance. Here, it is important to note the distinction between what Elizabeth and Robert Bjork call *storage strength* and *retrieval strength*.[29] Storage strength is the overall available amount of information, details, and skill that a learner has stored in their long-term memory. Retrieval strength is how accessible that information or skill is during actual performance.[30] Essentially, storage strength measures "how well learned an item is" and retrieval strength measures "the current ease of access to the item in memory."[31] The Bjorks argue that the current level of performance of a skill is determined by retrieval strength, but storage strength acts to slow forgetting and improve the relearning of a task in the future.[32]

After a memory has been retrieved, it is reconsolidated. Svard writes that the "very act of retrieving a memory of a piece" changes that memory because of all the additional learning that has taken place since the initial memory was formed.[33] For

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[29] Elizabeth L. Bjork and Robert A. Bjork, "Making Things Hard on Yourself, but in a Good Way: Creating Desirable Difficulties to Enhance Learning," in *Psychology and the Real World: Essays Illustrating Fundamental Contributions to* Society, ed. Morton Ann Gernsbacher, Richard W. Pew, Leaetta M. Hough, and James R. Pomerantz (New York: Worth Publishers, 2011), 58.
[30] Kathleen B. McDermott and Henry L. Roediger, "Memory (Encoding, Storage, Retrieval)," in *Noba Textbook Series: Psychology,* ed. R. Biswas-Diener and E. Diener (Champaign, IL: DEF Publishers, 2024), accessed March 15, 2024, http://noba.to/bdc4uger.
[31] Robert A. Bjork and Elizabeth L. Bjork, "A New Theory of Disuse and an Old Theory of Stimulus Fluctuation," in *Essays in Honor of William K. Estes*, vol. 2: *From Learning Theory to Connectionist Theory, 1935-1967*, ed. Anthony Healy, Stephen Kosslyn, and Richard Shiffrin (Hillsdale, NJ: Erlbaum, 1992), 42.
[32] Elizabeth Bjork and Robert Bjork, 58.
[33] Svard, 90.

example, a musician's interpretation of the piece may have changed, their technique may have improved, or they may have grown as a performer and musician more generally. To ensure that an existing memory fits within our current level of expertise, that memory must be reconsolidated as it is retrieved. As learning is reconsolidated, it becomes more refined and more readily available for retrieval in the future.

Table 1. The Stages of Memory.

Stage of Memory	Description of the Stage
Encoding	Sensory details are noticed and committed to memory. Memory traces of the piece are formed.
Consolidation	Memory traces are strengthened. More details are noticed, and errors are fixed.
Storage	Information addressed in the previous two stages is stored in long-term memory.
Retrieval	The brain reconstructs the various elements of the piece: visual, auditory, kinesthetic, motor.[34]
Reconsolidation	Memories are changed by the act of remembering them.

[34] Svard, 90.

Musical Applications of the Stages of Memory

Understanding the systematic stages of memory beyond an intuitive awareness should inspire musicians to practice in a manner best suited for long-term retention. For example, familiarity with the neurological encoding process can assist a musician when they approach a new piece. Additionally, understanding the difference between storage and retrieval strength can assist in understanding discrepancies between performance in the practice room and performance on stage. The consolidation and reconsolidation stages illustrate how learning is strengthened over time.

Although many of the concepts and strategies I discuss in the following chapters are related closely to long-term memory, this does not imply that the concepts and strategies contained in this paper are only valuable to those who wish to play music completely memorized (without the notated score). When musicians practice or perform with the score, they are retrieving knowledge and skills that they have learned and stored in their long-term memory. This includes technique, familiarity with the piece, and all the aspects of procedural and declarative memory necessary for performance. Although they use the notated score as a visual cue, they retrieve existing skill and knowledge from long-term memory to use in conjunction with their reading ability to successfully read and perform in real time. As such, even musicians with no interest in memorization will be able to utilize the concepts and strategies discussed in this paper to increase the efficacy of their practice.

Desirable Difficulties

While memory is crucial for performing musicians, the efficacy of their practice and the strength of their memory can suffer by neglecting to incorporate what are known as *desirable difficulties* into their practice. It is easy to shy away from difficulty when practicing, but difficulty is desirable when learning. Practice that feels easy does not guarantee long-term retention even if performance seems to improve within the practice session. Here, the distinction between learning and performance is an important guide. Robert Bjork writes the following regarding the difference between performance and learning:

> *Performance* during training is an unreliable indicator of the extent to which the *learning* that is the goal of training has been achieved. Conditions that yield a high rate of correct responses during training can fail to support performance in the post training environment; conversely, conditions that appear to slow or impede performance during training can enhance the subsequent real-world performance that is the target of the training.[35]

For musicians, the implication of these distinctions is that improvements in performance while practicing is not a reliable indicator that deep learning has taken place or that the improvements in performance will be retained in the long term. If musicians view performance during practice as a measure of learning, they "become susceptible to misassessing whether learning has or has not occurred."[36] Most musicians have experienced the phenomenon of improving a section of music substantially during practice only to flounder in performance or return to the practice room the next day and

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[35] Robert A. Bjork, "Institutional Impediments to Effective Training," in *Learning, Remembering, Believing: Enhancing Individual and Team Performance*, ed. Daniel Druckman and Robert A. Bjork (Washington, DC: National Academy Press, 1994), 299.
[36] Elizabeth L. Bjork and Robert Bjork, "Making Things Hard on Yourself, but in a Good Way," 57.

find that the learning did not stick. Some practice strategies may increase familiarity with the music, resulting in improved performance during practice, but may not lead to high-quality learning and retention between practice sessions.

An alternative, and perhaps unintuitive, metric for effective learning is the amount of cognitive effort the learner spends while practicing. Brown, Roediger, and McDaniel state that learners are "easily seduced into believing that learning is better when it's easier, but the research shows the opposite: when the mind has to work, learning sticks better."[37] It follows that if effortful learning is more effective, then musicians can increase the effectiveness of their practice through the use of what Robert and Elizabeth Bjork call *desirable difficulties*. They describe desirable difficulties as training conditions that create more difficulty during learning but lead to "more durable and flexible learning."[38] Certain difficulties "trigger encoding and retrieval processes that support learning, comprehension and remembering." However, some difficulties are undesirable if the learner "does not have the background knowledge or skills to respond to them successfully."[39] This means that the activity should generally just beyond the grasp of the learner's current skill level. If a practice activity is so difficult that the musician has no hope of reaching it, then it is unlikely to contribute to effective learning and the development of their mental representations.

In other words, a difficulty is desirable if it can be overcome and contribute to a greater level of skill and higher quality mental representations. If a practice activity is too

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[37] Brown, Roedieger, and McDaniel, *Make It Stick*, 43.
[38] Elizabeth and Robert Bjork, 58.
[39] Elizabeth and Robert Bjork, 58.

far out of a learner's current level of ability or is too unrelated to the task at hand, then it is undesirable and will not contribute to high-quality learning. Therefore, musicians should carefully leverage desirable difficulties and use them in a way that increases the quantity and quality of mental representations that are formed and refined while practicing. In the following chapters, I explore various research-based learning strategies that leverage desirable difficulties, fit into the framework of deliberate practice, and result in high-quality mental representations.

CHAPTER 3

RETRIEVAL PRACTICE AND TESTING

One of the most powerful learning strategies is retrieval practice. Retrieval practice requires the learner simply to test their performance of a specific skill before they review it through practice or to recall it directly from memory. This does not necessarily mean that practice should be done without reading the score, but rather that the performance of musical material should be judged by attempting to play it prior to any review. This allows the learner an accurate indicator of their current retrieval strength as it avoids the aid of the familiarity gained through repeated repetition. Testing is often seen as an assessment tool rather than a learning tool, but there is abundant research showing that testing oneself more frequently throughout the learning process greatly increases retention.[40] This phenomenon is known as the testing effect. While some initial practice is necessary to become familiar with material, research has shown that retrieval practice is far more effective at ensuring long-term retention than repeated exposure to material.[41]

For the sake of retrieval practice, it is helpful to delineate *declarative* and *procedural* memory.[42] Declarative memory, also known as explicit memory, is conscious and is the memory of facts, ideas, and concepts. Knowledge of how a piece sounds, the names of each pitch, the form, technique, and interpretation of the piece are examples of

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[40] Henry L. Roediger III and Jeffrey D. Karpicke, "The Power of Testing Memory: Basic Research and Implications for Educational Practice," *Perspectives on Psychological Science 1*, no. 3 (2006): 181.
[41] Brown, Roediger, and McDaniel, *Make It Stick*, 32.
[42] Svard, 83-84.

declarative memory. Procedural memory is unconscious, or implicit memory, and involves the execution of motor skills and cognitive processes.[43] In other words, declarative memory is something that you can speak about while procedural memory is something that you do. The ability to play an instrument and execute all the physical demands of a piece without consciously thinking about individual movements, or what musicians refer to as muscle memory, is an example of procedural memory. In the initial stages of learning a piece, the music resides in declarative memory as the notes are learned and physical movements are mapped out. Through practice, the physical movements necessary to play the piece become ingrained in procedural memory.

Retrieval practice benefits both declarative and procedural memory by ensuring that both can be readily accessed when needed. Recalling a piece of declarative memory, such as the given pitches in a passage, is a more obvious application of retrieval practice, but a musician can practice retrieval of a procedural memory by attempting a test performance of a passage or phrase before reviewing the muscle memory through practice. Lynn Helding, a voice professor at the University of Southern California's Thornton School of Music who researches the connections between cognitive science, neuroscience, and musical practice, created the following table that provides helpful distinctions between declarative and procedural memory.[44] However, the border between the two types is fuzzy as declarative memory can inform procedural memory and vice versa. For example, a musician may have a declarative memory of what emotive

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[43] Svard, 84.
[44] Lynn Helding, *The Musician's Mind: Teaching, Learning, and Performance in the Age of Brain Science* (Maryland: Rowman & Littlefield, 2020), 74.

character they would like a particular passage of music to sound like, but it is procedural memory that creates the physical movements necessary to produce the sounds that fit that character.

Table 2. A table describing Declarative and Procedural Memory from Lynn Helding's *The Musician's Mind* (recreated by Tony Kirk).

Declarative Memory	Procedural Memory
Propositional Explicit Controlled Learned Slow Demands attention Avoidable Volitional Know-that Top-down (via the executive control center of the brain)	Tacit Implicit Automatic Inherent Fast Can multitask Unavoidable Not volitional Know-how Bottom-up (via the autonomic nervous system)

Active Recall

Active recall is a retrieval practice strategy where, instead of reviewing material by rereading or re-exposure, the learner attempts to recall the desired skill or knowledge directly from memory. One straightforward way for musicians to implement active recall is to hide the sheet music of a given passage and attempt to recall everything about the it—including dynamic markings, pitches, rhythms, and the physical motions—directly from memory before reviewing the passage with the music. While it may seem counterintuitive to play from memory first instead of practicing the passage first and then attempting to recall it from memory, the increased struggle to retrieve the skill greatly improves long-term retention. This strategy not only improves and clarifies declarative memory but can also highlight areas where procedural memory is underdeveloped and hesitant. Analysis of a piece can help in developing retrieval strength as it provides more opportunities to connect declarative information to a larger mental representation about the piece. Additionally, active recall illustrates the effectiveness of practice away from the instrument for memorization and recall.

Active recall is also useful if the technical execution of a passage feels relatively comfortable, but interpretive clarity and accuracy of musical details fade in actual performance. The memory of musical details such as articulations and dynamics would fall into the category of declarative memory. In these instances, having a stronger declarative memory often also strengthens the procedural memory of producing those specific musical details by providing more context and specificity in retrieval.

Active recall can be deployed in many ways and need not be focused on comprehensive retrieval. For example, it is possible to utilize active recall by singing the pitches of a passage from memory using solfege, or declaratively stating articulations, dynamic markings, characters, and other musical details. Using active recall can identify discrepancies and hesitations in the mental representations used to play a specific passage. Some suggestions for application are given on the next page:

- Use solfege or note names to recall pitches. In music with multiple voices, recall voices one at a time, vertically (top to bottom or bottom to top), or in combinations of the voices (e.g., bottom three voices, top three voices, two middle voices, etc.).
- Recall specific interpretive details such as emotions, characters, and feelings.
- Write out the music from memory, including phrase markings, articulations, and other aspects of declarative information.
- Attempt to remember the harmonies of a specific section, noting similarities and differences between phrases.
- Create a formal diagram of the piece from memory and elaborate on the similarities and differences between sections or between that piece and the musical form in general. For example, while practicing a sonata, the musician can note how it either adheres to or deviates from their understanding of traditional sonata form. Additionally, they might note the differences between the original theme and the recapitulation.
- Recall all the articulations and/or dynamics present in a passage in the order that they appear.

Slow Practice as a Retrieval Strategy

Many musicians and teachers advocate for slow practice, but often it is not explained why slow practice is effective. Slow practice is effective because decreasing the tempo increases the amount of time available to think while playing. This is helpful for solidifying technical aspects of a passage by allowing time to think about each physical motion, but slow practice is primarily useful as a retrieval strategy. By increasing the amount of time between notes, the musician must think more deeply to accurately recall each note because slow practice alters the physical demands of a passage and thus decreases the ability to rely on existing muscle memory. This difficulty increases the quality of the encoding and consolidation of the material. To truly optimize slow practice, the tempo must be slow enough to be uncomfortable and make retrieval more cognitively difficult.

Slow practice is immensely helpful in developing declarative memory as it increases the difficulty of recall, but it may not always be helpful for developing or refining procedural memory as the motions used to play at an extremely slow tempo are very different from those used at fast tempos. Svard references the work of psychologist Karl Lashley, who observed that fast movements do not allow for consciously planning each movement and that, in the case of fast playing, a single motor program must encompass many movements.[45] A motor program is a type of procedural memory that can be equated with what musicians refer to as muscle memory. Grouping physical motions together into a single motor program is a function of another learning strategy

[45] Svard, *The Musical Brain,* 108-109.

known as *chunking*[46] and will be expanded upon later in the document. Slow practice can be useful for some technical problems by allowing space to think about the general choreography of the passage, but at a fast tempo, there is not enough time to consciously think about each motion. For this reason, slow practice is unlikely to help with issues of speed unless the inability to play a passage is caused by a lapse in declarative memory, which slow practice is well-suited to address.

An example of slow practice's utility while still developing the procedural memory used to play at full tempo is to use it in conjunction with fast or closer to tempo practice. Instead of starting slow and slowly increasing the tempo towards the performance tempo, alternate between practicing at a fast tempo to develop the proper motor program and practicing at a slow tempo to isolate issues of declarative memory. Practicing a passage from both a fast tempo and a slow tempo develops a more nuanced and comprehensive mental representation of that passage and ensures that neither declarative nor procedural memory is neglected. For example, consider the following excerpt from Lukas Ligeti's marimba solo *Thinking Songs*[47].

[46] Berg, 60.

[47] Lukas Ligeti, III. "Four-Part Invention," in *Thinking Songs* (Black Tea Music, 2015), p. 22, mm. 78-81.

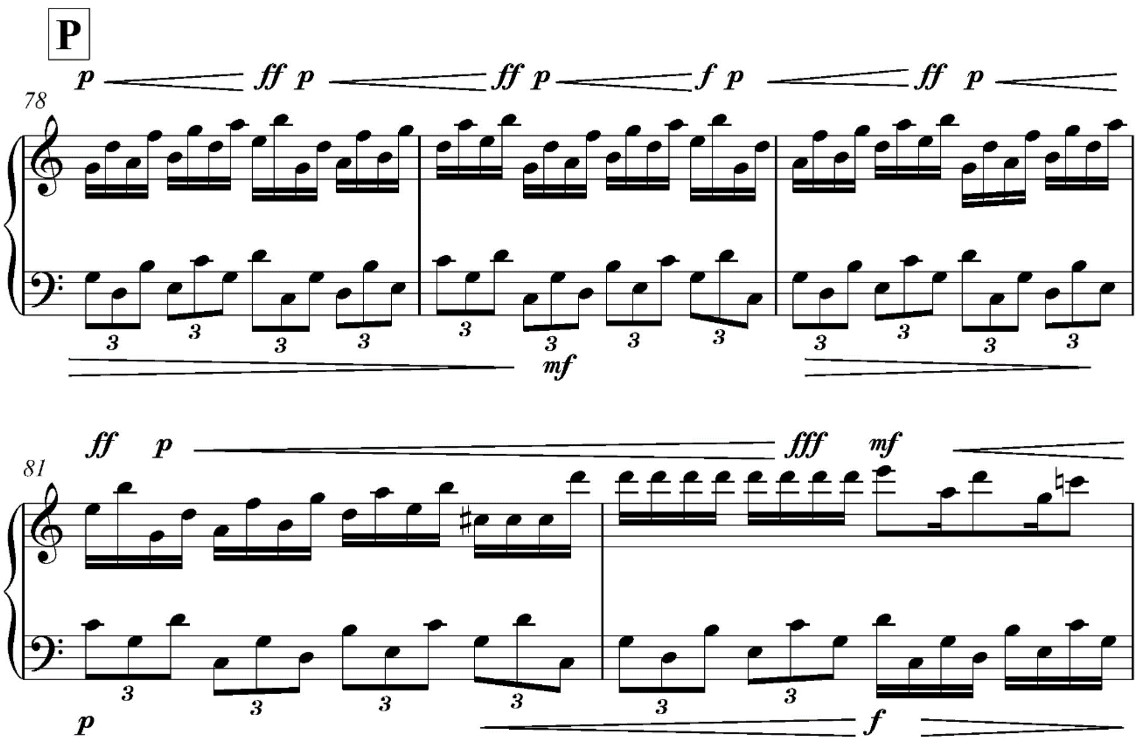

Figure 1. Lukas Ligeti, *Thinkings Songs*, III. Four-Part Invention, mm. 78-81.

In this passage, each hand plays its own pattern with independent dynamics. The right hand plays a pattern that is 10 sixteenth notes long. The left hand plays a pattern that is eight triplet-eighth notes long. The conflicting rhythmic patterns result in a passage that is difficult to learn and memorize. Although the measure must also be practiced at full tempo so that the motor program can be developed, clarifying declarative memory using slow practice can enhance the speed at which the declarative details of the excerpt can be learned, remembered, and played. A player can use slow practice to encode various checkpoints throughout the passage by noticing how the patterns interact throughout the passage with one another. Additionally, slow practice can clarify the overall physical and visual roadmap of the passage by allowing the player to notice and encode distinct physical and visual waypoints. After a period of using slow practice to solidify declarative memory of the passage, the excerpt can be tested at full tempo to determine which declarative aspects of the passage are solidified and which aspects must still be strengthened.

Playing from Memory and Recovering from Memory Slips - Retrieval Cues

A common assumption among musicians is that memory slips occur due to a disruption in the motor program. However, Svard argues that memory mistakes are due to lapses in recalling details of declarative memory.[48] To address memory slips, musicians must meticulously encode declarative information when they practice and draw upon the principles of effective memorization.

Research has shown that musicians rely on the same memorization principles that experts in other fields utilize. There are three main principles for effective memorization: meaningful encoding of the skill, use of a well-learned retrieval structure to access the skill, and practice to ensure rapid retrieval from long-term memory.[49]

The first principle of effective memorization involves meaningfully encoding the skill or knowledge being learned. In the context of music, this means going beyond procedural memory of the motor movements required to play a piece. In addition to learning the muscular movements to play a piece, musicians must also develop strong declarative memories that encompass the declarative musical details of a piece such as pitch, form, articulations, and dynamics. Some aspects of declarative memory in a piece of music are objective, such as pitch, form, and key, while others are subjective and

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[48] Svard, *The Musical Brain*, 94.
[49] Anders K. Ericsson and Walter Kintsch. "Long-Term Working Memory." *Psychological Review* 102, no. 2 (April 1995).

based on the musician's interpretation. For instance, a musician might create declarative memories by encoding details about the texture of a passage, specific imagery, or interpretive nuances. These instances of declarative memory are strengthened when integrated into larger mental representations about the piece.

The second principle of effective memorization is that the expert must create a retrieval structure, or a retrieval scheme, to access the skill from long-term memory. In a study observing a concert pianist learning, memorizing, and performing a new piece (the third movement of J.S. Bach's *Italian Concerto*), researchers Roger Chaffin and Gabriela Imreh discovered that the pianist developed a retrieval structure using various types of cues. These cues included *basic cues,* encompassing fingerings and technical details, *interpretive cues* for her musical interpretation of phrases, and *expressive cues* representing the feelings that the pianist wished to convey to the audience through her performance.[50] Interestingly, during a retrieval test conducted much later, they found that recall of measures containing expressive cues was notably stronger—although these measures were practiced the least of the three cues—than measures containing interpretive cues and basic cues, which had the poorest recall despite being practiced the most.[51] They suggest that expressive cues represent a higher level in the retrieval hierarchy, and practicing them "rechunked" the piece, establishing a new layer of cues in the retrieval hierarchy. This allowed the expressive cues to automatically trigger the necessary motor responses during performance. Conversely, the need to focus on specific technical details during basic cues led to poorer recall, as attention to these details left

[50] Roger Chaffin and Gabriela Imreh, "Practicing Perfection," 342.
[51] Chaffin and Imreh, 348.

fewer cognitive resources available for other features.[52] These findings suggest that having a strong foundation of technical skill can improve practice efficacy by decreasing the amount of time spent on technical issues in repertoire-specific practice and by leaving the musician space to focus on higher level cues like expressive cues or interpretative cues.

According to the study, these three cues were subsumed into the pianist's conceptual memory of the piece and her conceptual memory created a "hierarchical retrieval structure, organized into sections and subsections, with expressive phrases containing basic and interpretive performance cues…. making up the bottom levels." Due to the strength of her conceptual understanding of the piece (her mental representation) she was able to focus on expressive goals during performance while avoiding errors that might happen because of a wrong turn at a *switch*, which they define as points at which similar passages of material are differentiated from one another.[53] In the case that she did take a wrong turn, her conceptual memory of the piece served as "a means to recover."[54]

In summary, the study suggests that musicians should consider the various types of cues that they use while practicing and strive to connect them to a hierarchical retrieval structure guided by their conceptual understanding of the piece. This does not necessitate strict adherence to formal musical structure or theory for developing a conceptual understanding of the piece, but rather the identification of conceptual details that encompass lower-level cues into broader mental representations of the piece. Practicing

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[52] Chaffin and Imreh, 348.
[53] Chaffin and Imreh, 348.
[54] Chaffin and Imreh, 348.

these lower-level cues within the context of a hierarchical retrieval structure is essential for effective performance preparation.[55]

Using the Generation Effect

The generation effect is a learning phenomenon where a learner's active involvement in generating all or part of the material they are studying leads to better memory retention compared to passive review or rereading. [56] For instance, if individuals are presented with two lists of word pairs consisting of opposites, where one list contains both words (e.g., *Cold* and *Hot*), and the other requires them to generate the second word themselves (e.g., *Cold*, ___), they will recall the pair more effectively when prompted to generate the second word.[57] Essentially, the cognitive effort required to reconstruct fragmented information promotes deeper retention than simply reading complete words.

One method to implement this strategy is to select a musical phrase (or several) to memorize and conceal everything except the first measure of each phrase. Then, practice starting from the first measure to see if the entire phrase can be played. On the next page, I provide potentially ways to use the generation effect:

[55] Chaffin and Imreh, 348.
[56] Sharon Bertsch, Bryan J. Pesta, Richard Wiscott, and Michael A. McDaniel, "The Generation Effect: A Meta-Analytic Review," *Memory & Cognition* 35, no. 2 (2007): 201.
[57] Bertsch, Pesta, Wiscott, and McDaniel, 201.

- Conceal the pitches but provide the harmony.
- Provide the melody but omit the accompaniment.
- Show the accompaniment without the melody.
- Conceal the rhythm but provide the pitches.
- Display the rhythm but not the pitches.
- Provide only one or two beats per measure, not necessarily consecutively.
- Conceal all even measures and reveal odd measures, and vice versa.
- In pieces with multiple voices, conceal one or more voices while providing one as written.

For an illustration of the generation effect, consider the following excerpt from Lukas Ligeti's *Thinking Songs*. This passage poses challenges in learning and memorization due to its limited pitch range, repetitive rhythms, and lack of easily identifiable phrases. Consequently, it is easy to make continuity mistakes due to the difficulty of developing clear motor programs that account for the differences between measures. To combat this, the generation effect can be leveraged to differentiate between the declarative and procedural memories of each measure, increasing retrieval in performance. The examples below demonstrate various ways the generation effect can be employed to practice this excerpt.

Figure 2. Lukas Ligeti, *Thinkings Songs*, III. Four-Part Invention, mm. 67-72.

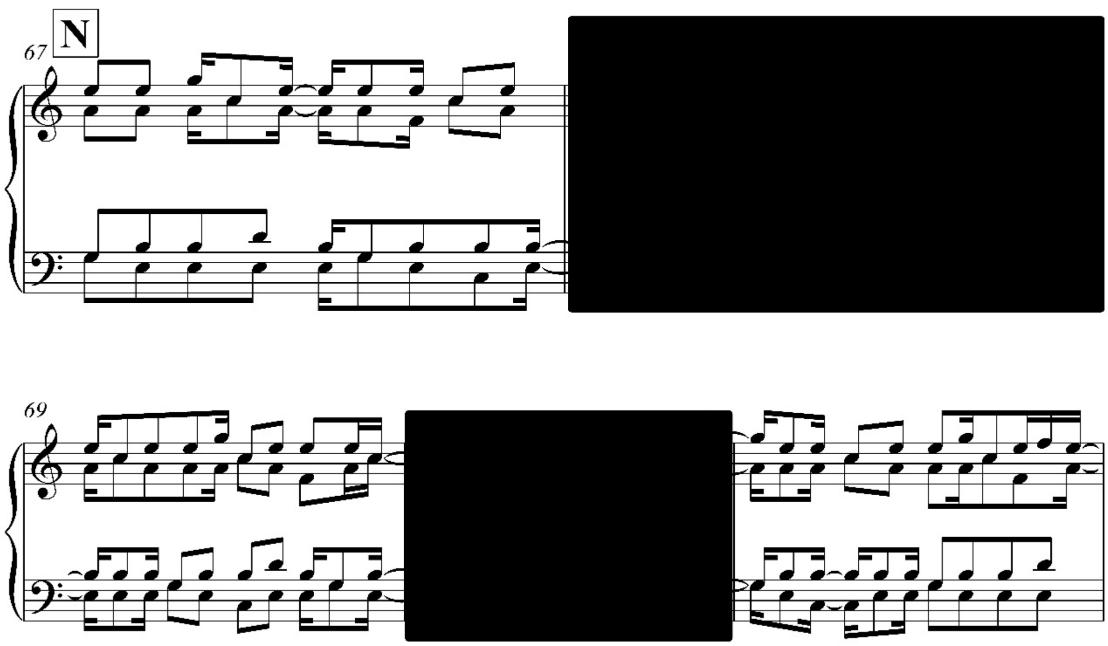

Figure 3. mm. 67-72, hiding every even measure.

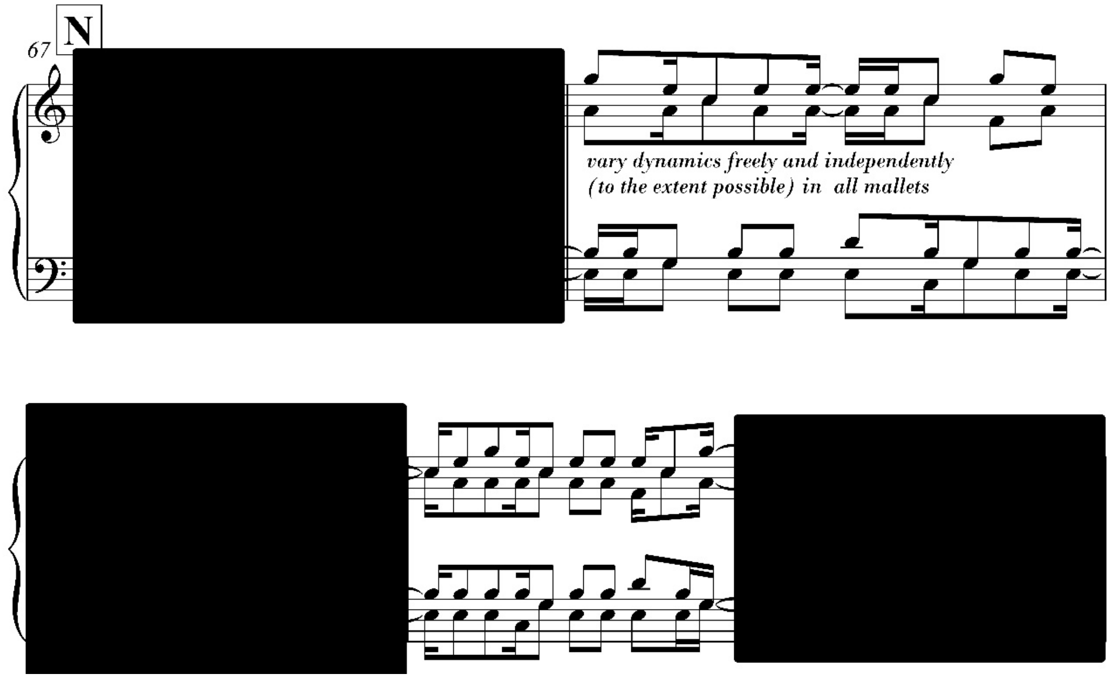

Figure 4. Hiding every odd measure.

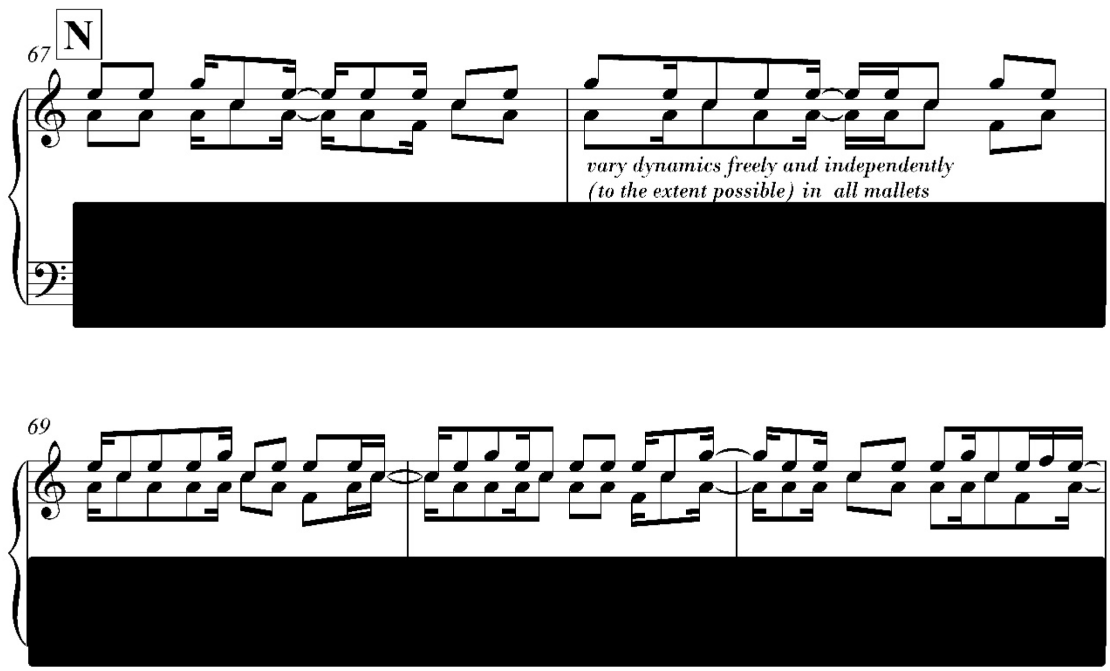

Figure 5. Hiding the bottom staff.

Figure 6. Hiding the top staff.

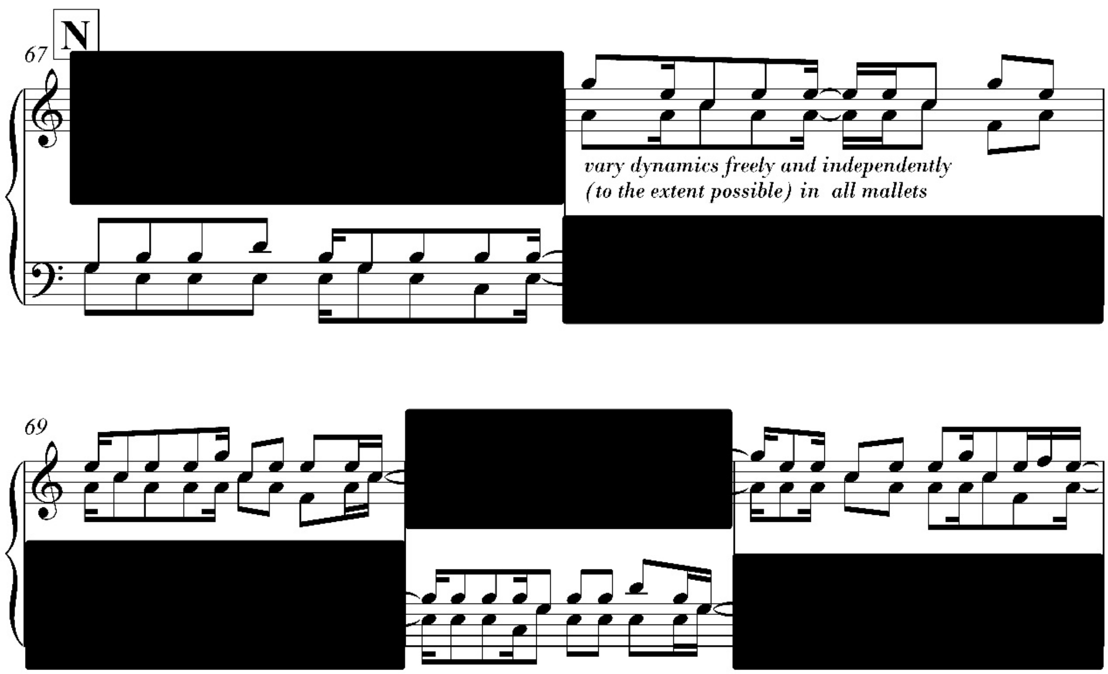

Figure 7. Alternating hiding the top staff and bottom staff.

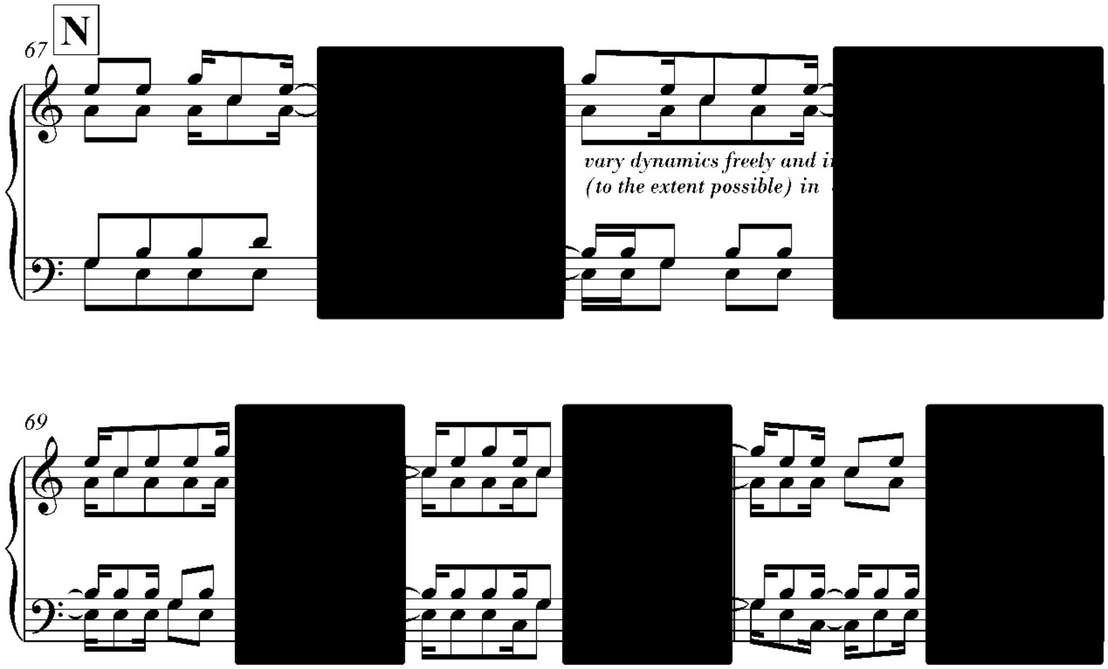

Figure 8. Hiding beats 3 and 4 of each measure.

CHAPTER 4

SPACED REPETITION

In the previous chapter, I discussed the effectiveness of retrieval practice, or the testing effect, as a learning strategy and suggested applications for musicians. In this chapter, I discuss how allowing space between practice sessions of a particular skill can increase practice effectiveness. I suggest a variety of potential applications of spaced repetition for musical practice, such as spacing practice sessions throughout a day, adjusting spacing intervals based on existing fluency with material, and using spaced repetition as a quantifiable metric for memorization.

Brown, Roediger, and McDaniel write that a number of studies show that spacing practice sessions of a skill over an extended period leads to superior learning outcomes and longer-lasting retention compared to massed practice, where the same amount of practice is condensed into a shorter timeframe. [58] The implication for musicians is that practicing for shorter durations spread out over several days will lead to better mastery and recall than cramming the same amount of practice into a single day. Spaced repetition is effective because new learning needs to be encoded into long-term memory, and the consolidation of that learning is a process that unfolds over hours or even days, allowing for digestion of the new information in the brain and its integration with prior knowledge.[59]

A study cited by Brown et al. tested the effects of spaced repetition (also known as spaced practice) on learning calculus. In the study, the researchers tested engineering

[58] Brown, Roediger, and McDaniel, 47-49.
[59] Brown, Roediger, and McDaniel, 48-49.

undergraduate students by changing the structure of their quizzes and assessments over the length of a semester long course. The course had a total of 24 learning objectives and there were three questions for each learning objective throughout the entirety of the course. The odd-number objectives were practiced using a massed practice schedule: All three questions relating to the objective would appear on the first quiz after the learning objective's introduction in the course. The even-number objectives were practiced using spaced repetition, with one question appearing in the first quiz after the objective's introduction, the next question appearing in the next quiz, and the final question appearing on the next quiz after that. A final test that included all 24 learning objectives was administered 15 weeks after the start of the course on the final day of class. The study found that spaced practice initially resulted in worse performance on the quizzes compared to massed practice but had a statistically significant increase in performance on the final test.[60]

Spaced repetition is effective because it disrupts what psychologists refer to as the *forgetting curve*, a concept first described by Hermann Ebbinghaus in 1885. In his experiments, Ebbinghaus tested the rate of forgetting newly learned information by attempting to memorize a series of nonsense syllables. His research revealed that after the initial learning, information was quickly forgotten, but that subsequent retrieval of the material slowed the rate of forgetting—resulting in a flattened curve over time. Moreover, he observed that relearning the forgotten information between practice

[60] Keith B. Lyle, Campbell R. Bego, Patricia A. S. Ralston, and Jason C. Immekus, "Spaced Retrieval Practice Imposes Desirable Difficulty in Calculus Learning," *Educational Psychology Review* 34 (2022): 1799–1812.

sessions took less time with each subsequent practice session. [61] Ebbinghaus's research included only himself as a test subject, but the forgetting curve has been replicated recently in more clinical studies.[62]

Spaced repetition serves as a powerful practice tool to counteract the forgetting curve by continuously reinforcing learned material in long-term memory. It enhances retrieval practice by introducing a controllable level of difficulty, through increasing or decreasing space between practice sessions, and allowing forgetting to occur. As information is forgotten between practice sessions, the learner must then work harder to recall that information. Overcoming this desirable difficulty results in stronger and more durable retention of the retrieved information or skill in long-term memory.

Space Practiced Schedules

One easy way to implement spaced practice is to plan multiple practice sessions throughout a day rather than planning only one long session. In addition to disrupting the forgetting curve, spacing practice of one kind of material helps prevent mental and physical fatigue. By spacing out practice sessions, learners engage in retrieval practice more frequently, reinforcing their understanding of the material. Despite covering less material in each session compared to a single longer practice session, the depth of learning is enhanced, particularly if the material is new.

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[61] Hermann Ebbinghaus, "Memory: A Contribution to Experimental Psychology," *Classics in the History of Psychology*, trans. Henry A. Ruger & Clara E. Bussenius (1913), accessed March 2024. https://psychclassics.yorku.ca/Ebbinghaus/memory8.htm, internet resource developed by Christopher D. Green.
[62] Jaap M. J. Murre and Joeri Dros, "Replication and Analysis of Ebbinghaus' Forgetting Curve," *PLoS ONE* 10, no. 7 (2015): e0120644.

As material becomes better learned, the timing between practice sessions on that material can be increased, leading to greater learning and long-term retention. For instance, if new material is learned in a practice session, it is beneficial to review it very soon after the initial session to reinforce the memories created. However, as the skill or knowledge becomes more firmly established in memory, the spacing window can be gradually increased. This might involve practicing the material once a day initially, then progressing to every other day, then twice a week, and eventually reducing it to once a week or even less frequently. Spaced repetition benefits the encoding of material by spreading the learning out over a longer period, but it also increases retrieval strength by making retrieval more difficult.

There are two ways to implement spaced practice schedules. One method is to use an equally spaced practice schedule, where the time between practice sessions is consistent. For example, practicing a particular piece every three days would be an equally spaced schedule. Another approach is to use an expanding schedule, where the time between initial practice sessions starts low and increases relatively over time. For instance, practice sessions might be scheduled one day apart initially, then two days apart, four days apart, and so on, with increasing intervals between sessions. A study by Karpicke and Bauernschmidt investigated the impact of these two scheduling methods on learning. Their findings suggest that expanding schedules offer a way to steadily increase the difficulty of retrieval but the method of spacing out practice sessions, equally or expanding, does not significantly affect retention of the material. Instead, it is only increasing the absolute spacing between practice sessions that matters for continuing to increase long-term retention.[63]

Using Spaced Practice for Material at Various Stages of Development

Spaced repetition is a good litmus test for how well material is learned and can be used as a guide to choose which items should be practiced each day. Fresh material must be practiced more frequently, perhaps every practice session. Material that is learned but still developing can be practiced regularly, but it is likely not necessary to practice it every day. Material that is very well-learned or easily within grasp likely will not benefit from frequent practice sessions. In such cases, spaced repetition can be used to reintroduce a desirable difficulty to familiar material, thereby increasing the quality of learning. Below is a table that illustrates how spaced repetition might be applied to material at various stages of development.

Table 3. Spaced practice schedule for material in different stages of development.

Type of Material	Session 1	Session 2	Session 3	Session 4
New Material	Practice	Practice	Rest	Practice
Developing Material	Practice	Rest	Practice	Rest
Well-Learned Material	Practice	Rest	Rest	Practice

[63] Jeffrey D. Karpicke and Althea Bauernschmidt, "Spaced Retrieval: Absolute Spacing Enhances Learing Regardless of Relative Spacing," *Journal of Experimental Psychology: Learning, Memory, and Cognition* 37, no. 5 (2011): 1255-1256.

The new material is practiced most frequently, in sessions 1, 2, and 4. It is practiced on consecutive sessions at first because it is fresh material and must be reviewed often to counteract the forgetting curve. The developing material is practiced with a larger spacing interval between sessions; it is only practiced in session 1 and session 3. Because the well-learned material is already comfortable, it is only practiced during the first session and the last session. Although this example includes only four practice sessions, the principles described here can be extrapolated and applied over a longer period and more practice sessions.

Of course, the reality of practicing is that not every section of a single piece will always have the same ease of retrieval. The solution is to break apart a piece into multiple sections, determine the initial level of comfort with the material in each section via retrieval practice, and plan spacing intervals for each based on how well-learned the material feels.

Using Spaced Practice with Well-Learned Material

If a passage is already well-learned but does not improve with frequent practice, increasing the amount of time between practice sessions can help to break a so-called learning plateau. Although counterintuitive, stepping away from a piece or passage for a longer period of time (days or weeks) can increase the quality of learning when the piece is eventually returned to. Taking a break from a piece allows a little forgetting to occur and reintroduces novelty when the piece is returned to. Svard writes that “the brain likes novelty” and that, when the material is returned to after a break, the brain will pay more attention and notice more information to encode.[64] Additionally, increasing the amount of time between practice sessions of well-learned material can reintroduce cognitive effort to the practice of otherwise familiar material.

Using Spaced Retrieval Practice to Quantify Memorization

When practicing musical material at various stages of development, it is difficult to quantify how well memorized all the individual pieces or parts of pieces are. It is also difficult to assess whether mistakes are made because of technical deficiencies or lapses in memory. Spaced retrieval practice is also useful in diagnosing the cause of mistakes during performance, particularly for making distinctions between memory errors and technical issues. Using spaced retrieval practice to specifically test memorization, separately from technical work, can assist in quantifying memorization and prevent time from being wasted on the wrong skill. Here, active recall is helpful, as thinking through a passage without physically playing removes technical challenges and isolates issues of memory.

Likewise, the consistency of procedural memory may be tested through spaced retrieval practice. For example, a percussionist might implement spaced retrieval practice on a standard orchestral excerpt such as the xylophone part to the opening of George Gershwin's *Porgy and Bess*, an excerpt that is frequently required for orchestral auditions and generally practiced for an extraordinary amount of time over a percussionist's career. The excerpt is easy to memorize and instead challenges speed and consistency in basic xylophone technique. Rather than devoting frequent practice to the excerpt, a

[64] Svard, 104.

percussionist can instead use spaced retrieval practice as a diagnostic tool for the performance of this excerpt. If the excerpt is performed well on the first attempt, then the percussionist can confidently prioritize other pressing tasks, saving time and energy. If the excerpt does not meet the desired level of performance, then the percussionist knows they must devote practice time to it.

The information gained from spaced retrieval practice can be used to plan future practice sessions and determine how to space future practice sessions of the material. If recall of a passage comes easily, it can be practiced less frequently. If there are multiple stumbles or hesitations to recall a passage, it should be practiced more frequently. Throughout this process, keeping the number of repetitions low helps in quantifying the performance of the material. If there are inconsistencies in the technical execution of a passage, but not in recalling the declarative memory of the passage, mistakes can be ascribed to issues with technical development and not the memory of the passage.

On Massed Practice

Massed practice may be retained momentarily, but unless the material is encoded very deeply, retrieval strength will be low as the material will not have gone through the processes of continual consolidation, retrieval practice, and reconsolidation. However, there are instances where crammed or massed practice may be examples of extreme spaced repetition. For example, a musician might start to prepare a piece they have played before only a few days before a performance. This may seem like an example of massed practice, but due to their prior practice of the piece they will likely be able to create a successful performance in that time frame. In these instances, the performer is primarily relying on their existing mental representations, their prior practice of that piece, and their overall level of musical and technical ability. As such, it can be an example of extreme spaced repetition of that piece, application of their general abilities, and improving the much more general skill of learning music quickly (which relies on forming high-quality mental representations). It is unlikely that they will encode new learning during this condensed time frame, but that is not to say that massed practiced has no worth or is never necessary. However, the circumstances leading to massed practice usually cause musicians to rely on their existing mental representations and skills and as such are not always the best for stretching one's abilities.

CHAPTER 5

INTERLEAVED PRACTICE

In Chapter 4, I discussed the strategy of spaced repetition and suggested a variety of ways that it can be used for musical practice, such as utilizing spaced practice schedules, using spaced repetition as a metric for memorization, and adjusting spacing intervals based on the current comfort level with certain material. In this chapter, I discuss interleaved practice, a strategy in which the practice tasks of a practice session are alternated frequently rather than practicing each task to completion before moving to the next.

A typical practice session might involve two hours of total practice, with 30 minutes spent on warming up and technical exercises, and the remaining 90 minutes equally allocated to three pieces of repertoire to be practiced one after the other. This approach of practicing one task until completion before moving to the next is known as massed or blocked practice. Musicians frequently employ massed practice, often at the recommendation of their teachers, as it is widely believed that focusing solely on one task before proceeding to the next is the most effective way of addressing musical or technical challenges.

However, research has shown that *interleaving* practice, or alternating between practice tasks during a practice session rather than practicing one task until mastery is achieved, is more effective for learning and long-term retention than blocked practice. For example, instead of practicing each piece of repertoire consecutively for 30 minutes each, a musician could instead interleave their practice by switching between each repertoire piece every ten minutes.

Interleaved practice has been proven to be effective across many different domains, including cognitive skills such as solving mathematics problems[65] and motor skills like baseball.[66] One study tested interleaved practice with collegiate clarinetists who practiced one excerpt and one concerto exposition using blocked practice and a second concerto and excerpt using interleaved practice. The results of the study showed that the pieces practiced using the interleaved condition were rated more highly by the judges, suggesting that interleaved practice is more effective.[67]

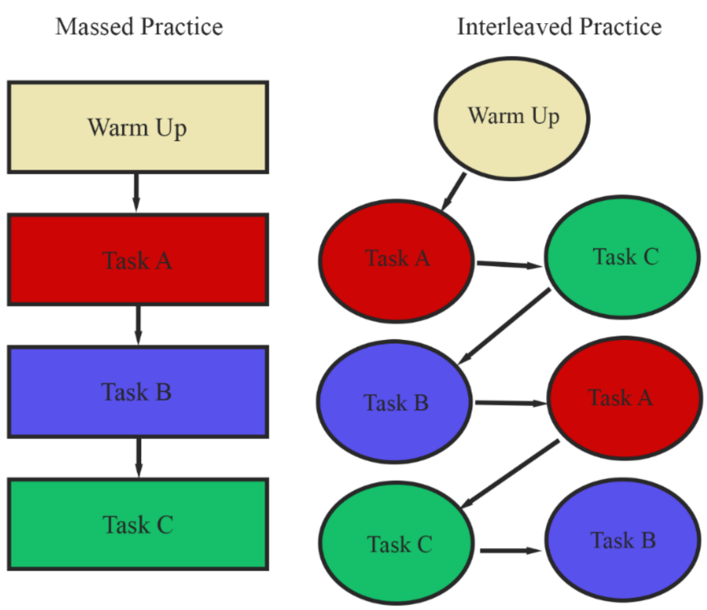

Figure 9. Massed vs. interleaved practice schedules.

[65] Brown, Roediger, McDaniel, *Make It Stick*, 50.
[66] Kellie G. Hall, Derek A. Domingues, and Richard Cavazos, "Contextual Interference Effects with Skilled Baseball Players," *Perceptual and Motor* Skills 78, no. 3 (1994).
[67] Christine E. Carter and Jessica A. Grahn, "Optimizing Music Learning: Exploring How Blocked and Interleaved Practice Schedules Affect Advanced Performance," *Frontiers in Psychology* 7 (August 2016)

Students consistently prefer massed practice even when they have experienced the increased performance gains of interleaved practice[68] as performance appears to improve more quickly than in interleaved practice. However, the gains from massed practice are what Brown et al. refer to as an *illusion of knowing*. They write that massed practice "gives us the warm sensation of mastery because we're looping information through short-term memory without having to reconstruct the learning from long-term memory."[69] Interleaved practice, due to the interruptions to short-term memory by frequently switching between tasks, forces the learner to reconstruct learning from long-term memory, which leads to better reconsolidation and deeper learning.

At the same time, interleaved practice is more effective than massed practice because of the *contextual interference effect*. The contextual interference effect suggests that interference while learning—by switching between different types of tasks while practicing—leads to poorer performance in the short term, but better retention long term.[70] In other words, contextual interference is a desirable difficulty.

There are a few hypotheses for why contextual interference works. The first is called the elaboration-distinctiveness hypothesis. This hypothesis posits than when similar tasks are interleaved, the brain must hold similar tasks in working memory and "thus more elaboration is required to distinguish tasks from one another, leading to a

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[68] Carter and Grahn, "Optimizing Music Learning: Exploring How Blocked and Interleaved Practice Schedules Affect Advanced Performance," 7.
[69] Brown, Roediger, and McDaniel, 82.
[70] John B. Shea. and Robyn L. Morgan. "Contextual Interference Effects on the Acquisition, Retention, and Transfer of a Motor Skill." *Journal of Experimental Psychology: Human Learning and Memory* 5, no. 2 (1979).

more durable encoding."[71] Another theory is that when practice is interleaved, forgetting occurs between interleaved attempts and the learner must reconstruct the skill by retrieving it from memory. This hypothesis is called the forgetting-reconstructive hypothesis. When a task is practiced with massed practice, it is continually refreshed in working memory and therefore there is no forgetting and reconstruction, resulting in poorer long-term retention.[72] Interleaved practice forces learners to engage in retrieval more frequently, strengthening reconstruction and making the skill or knowledge more likely to be retained in long-term memory. In the following section, I give several suggestions for applying the principles of interleaving to musical practice.

Interleaving Using Time or Number of Repetitions

One way to incorporate interleaved practice is to interleave practice tasks after a set number of repetitions or after a set amount of time. Interleaving based on repetition can be helpful when there are several challenging spots to be practiced and works best with isolated problems. For example, three to five similar technical problems in a piece could be set aside to be practiced in one ten-minute period. During that ten-minute period, the musician could alternate between which problem is being practiced every three to five repetitions. This works best when mental representations and musical goals are already clear, and consistency of technical execution and ease of recall is the main goal.

[71] Julie M. Schorn, Hongjing Lu, and Barbara J. Knowlton. "Contextual interference Effect in Motor Skill Learning: An Empirical and Computational Investigation," *Proceedings of the Annual Conference of the Cognitive Science Society 42* (2020): 2043. https://par.nsf.gov/biblio/10250913.
[72] Schorn, Lu, and Knowlton. 2043

Interleaving based on time can be more flexible and is easier to use with larger blocks of material. For example, if material is well-learned already, it can be interleaved using short practice segments of only a few minutes before moving onto another practice task. If the task is to learn new material, then larger time segments can be helpful to ensure that some progress is made before moving on to another task. This is helpful to still gain the benefits of interleaving but ensure that enough time is given to develop high-quality mental representations of what is being practiced.

Interleaving Problematic Areas Throughout a Practice Session

Another way to utilize interleaving is to isolate technical problems and interleave them throughout the entirety of a practice session. To do this, select a few problematic areas to be interleaved and return to them for a few repetitions or minutes repeatedly throughout a practice session. This can be helpful to make sure that problematic areas receive attention multiple times over the course of a practice session without disrupting the goals of a practice session. Additionally, the contextual interference that occurs as a result of switching frequently between challenging tasks serves to cement these areas in the mind.

Distinguishing Between Similar Material and Patterns

Another good use of interleaving is to take a passage that is complex and break it down into a few sections of self-similar material. Then interleave the practice of those sections to develop the ability to distinguish each section from one another. This is especially helpful for material that is similar and contains patterns or repetition. For example, in the following passage from Ligeti's "Four-Part Invention," it is difficult to encode clear declarative and procedural memories because the material is similar throughout, aurally and physically.

Figure 10. Lukas Ligeti, *Thinking Songs*, III. Four-Part Invention, mm. 67-73.

To use interleaved practice for this passage, practice each measure independently for a few repetitions or minutes before moving onto another measure. The measures do not necessarily need to be practiced in the order that they appear in the score and being able to recall them independently, out of context, can strengthen recall.

CHAPTER 6

VARIED PRACTICE

The previous chapter addressed interleaved practice, a strategy in which practice tasks are alternated rather than consecutively practiced to completion and provided its benefits and potential applications for musical practice. In this chapter, I discuss varied practice, a strategy in which the variables of a task are altered or the conditions of practiced are changed to create desirable difficulty for a practice task for the sake of more durable learning.

One study referenced by the Bjorks showed that participants who studied material in two different rooms had greater recall than those who studied the material in the same room twice.[73] Another study tested the effect of varied practice by comparing two groups of children throwing bean bags at a target on the floor from a fixed distance. One group always practiced at the distance from which they would be tested, and the other group practiced throwing the bean bags at targets that were either farther or nearer, but never at the distance that would be tested. The children who practiced using conditions that were varied—the group that threw bean bags at a target either closer or farther than the tested target—performed better than those who only practiced at the tested distance.[74] The Bjorks state that when practice occurs under predictable conditions, the learning tends to become contextualized. The material is easily retrieved in the context that it was learned

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[73] Steven M. Smith, Arthur Glenberg, and Robert A. Bjork, "Environmental Context and Human Memory," *Memory & Cognition* 6, no. 4 (1978): 342–353, https://doi.org/10.3758/BF03197465.
[74] Robert Kerr and Bernard Booth, "Specific and Varied Practice of Motor Skill," *Perceptual and Motor Skills* 46, no. 2 (1978): 395.

but learning in this way does not support future performance if "tested at a delay, in a different context, or both."[75]

By varying the conditions of practice, a more robust mental representation of the skill is learned as well as the ability to transfer learning to a variety of contexts, resulting in what Brown et. al call a more flexible "movement vocabulary."[76] Brown writes that recent studies suggest that different types of practice engage different areas of the brain and that motor skills learned from varied practice appear to be consolidated in an area of the brain "associated with the more difficult process of learning higher-order motor skills."[77] Motor skills learned from massed practice appear to be consolidated in a different area that "is used for learning more cognitively simple and less challenging motor skills."[78] Brown suggests that learning gained from a "less challenging, massed form of practice is encoded in a simpler or comparatively impoverished representation than the learning gained from the varied and more challenging practice which demands more brain power and encodes the learning in a more flexible representation that can be applied more broadly."[79] Below are few applications of these strategies for musicians.

[75] Elizabeth and Robert Bjork, 58.
[76] Brown, Roediger, McDaniel, *Make It Stick*, 51.
[77] Brown, Roediger, McDaniel, 51.
[78] Brown, Roediger, McDaniel, 51.
[79] Brown, Roediger, McDaniel, 51-52.

Vary the Location of Practice and Performance

Varying the location of practice is relatively simple to implement. The study illustrated that practice in different spaces led to increased recall.[80] This is most likely because changes in acoustic environment is a desirable difficulty because it stimulates changes in how one might play, resulting in more robust mental representations. If one's instrument is small and mobile, an individual may try to practice in different rooms of their living space to vary acoustic conditions. If attending a music school, one can change which practice rooms they frequent, hopefully seeking out rooms that have significant variance from one another. For instance, if one generally practices in a room with a lot of resonance, one can occasionally seek out a room that is less resonant.

Varied Instruments

Interestingly, the principles of varied practice suggest that changing the instrument being practiced or performed on—typically seen as a disadvantage for percussionists and pianists—might lead to better long-term performance. Adjustments must be made when learning how different instruments respond to playing. This provides the opportunity to develop more complex mental representations about various musical parameters involved with playing, such as touch, tone, dynamics, and more. Practicing on a multitude of instruments offers the opportunity to think deeply about the sound and strengthens control of technique. For instance, there is little standardization of mallet percussion instruments, and even instruments of the same model have their own unique quirks. One xylophone may be slightly larger or smaller than another, resulting in minor

[80] Smith, Glenberg, and Bjork.

changes to motor programs. Another instrument might have different qualities of tone and inconsistencies in how well individual notes speak—requiring adjustments to how a passage might be approached musically. However, these variations help develop flexibility in playing and prepare musicians for a variety of performance situations. Moreover, this approach has real-world applications for percussionists who frequently encounter unfamiliar instruments at auditions and gigs. A percussionist may incorporate this strategy by intentionally alternating between instruments during practice sessions. Other instrumentalists might incorporate this strategy by practicing on different instruments, alternating between what reeds or mouthpieces they use, and so on.

Varied Rhythm

Varying the rhythms of a passage is a common practice in varied practice. For instance, many musicians recommend using dotted rhythms to practice fast and technically challenging passages. This approach offers several benefits: It provides more time between each successive group of notes, allowing for thoughtful consideration of what comes next (similar to the benefits of slow practice), while also maintaining the proper rhythmic spacing between notes in a group. Additionally, practicing with dotted rhythms requires muscle movements more similar to those needed at performance tempo, which can be difficult to achieve with slow practice alone. Moreover, changing the rhythm can disrupt existing memory, making retrieval more challenging and thus more valuable for learning. In the example below, an excerpt from Ligeti's Four-Part Invention has been transformed from consecutive eighth notes into two exercises that alter rhythmic groupings. However, various rhythms can be used for experimentation. Practicing with different rhythms ensures that the practice remains varied and that all aspects of connecting the motor program are considered.

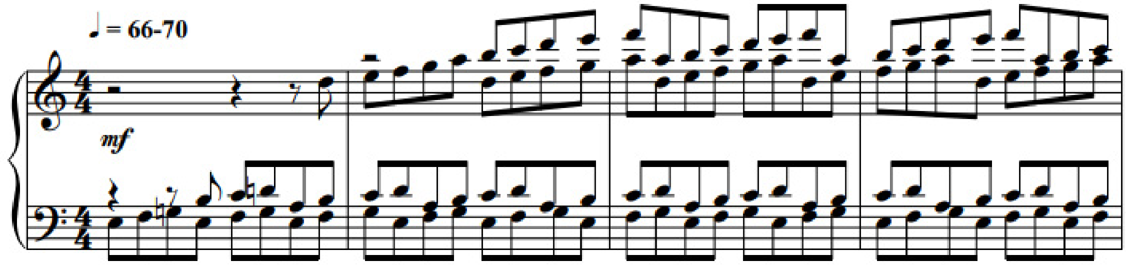

Figure 11. Lukas Ligeti, *Thinking Songs*, III. Four-Part Invention, mm. 1-4.

Figure 12. Measures 1 and 2 with the rhythm varied.

Figure 13. Selection of the passage with its rhythm transformed into three-note groupings.

Varied Phrasing/Dynamics

In this case, the performer alters the dynamics or inflection of a passage. By varying the dynamics, individuals can gain a deeper conceptual understanding of the musical elements at play and enhance their comprehension of the written dynamics by experiencing how the passage would sound in different contexts. This fosters a more flexible and comprehensive grasp of technique in general, as well as its application to specific passages. Furthermore, practicing across a range of phrasings and dynamics enhances performance flexibility, enabling better real-time control during performances. In the following excerpt from Ligeti's Four-Part Invention, the challenge lies in controlling dynamics independently between each voice. Subsequent exercises have been developed to vary the dynamics in various ways, aiming to cultivate the skill of maintaining independent dynamics between voices.

Figure 14. Lukas Ligeti, Thinking Songs, III. Four-Part Invention, mm. 50-53.

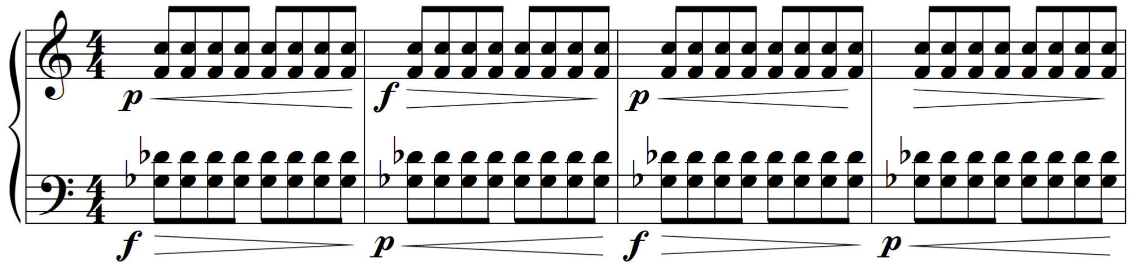

Figure 15. An exercise targeting the ability to control dynamics independently in each hand.

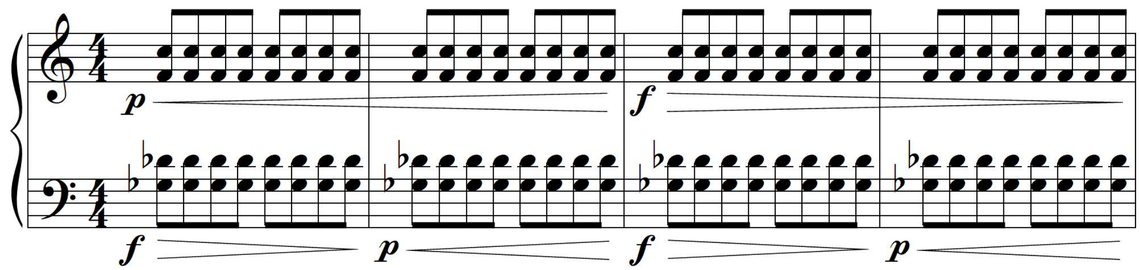

Figure 16. Variation on the previous exercise.

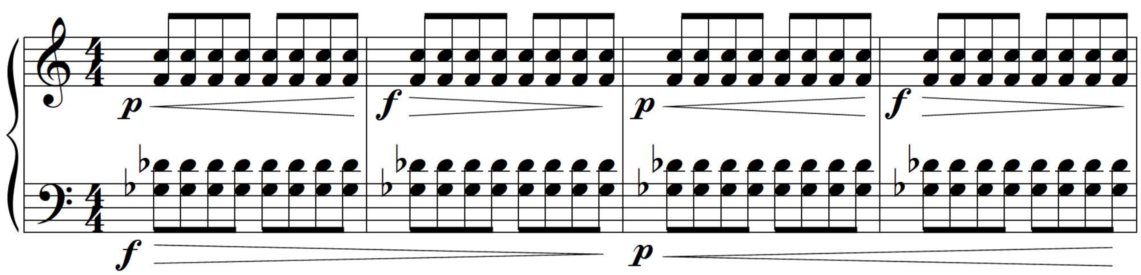

Figure 17. Another variation on the previous exercise.

CHAPTER 7

CHUNKING

In the preceding chapters, I explored various learning strategies, such as retrieval practice, spaced repetition, interleaved practice, and varied practice. Each of these strategies leverages desirable difficulties to facilitate effective and durable learning. In this final chapter of this portion of the document, I explore *chunking*, first defined by George A. Miller in 1956. Chunking enables learners to recontextualize isolated units of material as parts of meaningful groups, helping to overcome the limitations of short-term memory and enhancing effective practice.

Scores are often densely packed with seemingly individual units of musical information. For musicians striving to increase their mental capacity, developing a systematized approach to the grouping of adjacent material is essential to reducing mental load during performance. While researching the limits of immediate memory, Miller found that the average person can hold about seven units of information in their immediate memory at any given point in time. It is not possible to increase the number of units that a person can remember, but it is possible to increase the amount of information—which Miller calls *bits*—contained by each unit by creating meaningful groups, *chunks*, out of that information. [81] Material divided into chunks is easier to remember because the material contained in the chunks are often related to one's prior

[81] George A. Miller, "The Magical Number Seven, Plus or Minus Two: Some Limits on our Capacity for Processing Information," *Psychological Review* 101, no. 2 (1994): 343-352.

knowledge. For example, the numbers 6, 0, and 2 can be made into a chunk if they are thought of as the area code for Phoenix, Arizona.

Creating chunks reduces cognitive strain and increases overall mental capacity. Someone told to remember the letters "C, E, G, F, A, C, G, B, D, C, E, G" might struggle; the amount of total information is larger than the number seven, the average limit for immediate memory. However, if they were to relate these letters to their musical expertise, by thinking about them as pitches, they could create meaningful chunks by grouping them into triads arrayed around simple harmonies: C major, F major, G major, and back to C major. This practice reduces the number of material units from 12 to 4, helping to make memory more facile. In this case, the chunking can continue through a second iteration. The musician might also group these four triads as a I-IV-V-I harmonic progression in C major.

While chunking is best deployed with conceptual information, it is also valuable for grouping physical skills. Physical skills can be chunked by recognizing a series of smaller movements that can be grouped into one larger chunk of motions. These series of motions are referred to as "motor chunks."[82] When a new physical skill is being learned, each motion is thought of independently and is performed very deliberately, but as fluency develops the isolated movements become part of larger groups of physical gesture, and through practice it becomes possible to chunk those movements into larger groups. This can be accomplished by taking a skill, identifying its component physical

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[82] Krishn Bera, Anuj Shukla, and Raju S. Bapi, "Motor Chunking in Internally Guided Sequencing," Brain Sciences 11, no. 3 (2021): 292, https://doi.org/10.3390/brainsci11030292

motions, grouping small motions into a larger physical gesture, and practicing those chunks individually before them together.

Essentially, chunking is grouping material together in a meaningful way that makes future recall easier, physically and conceptually. When a musician reads music, they often do not process each individual note as separate entities, but instead recognize patterns, harmonies, intervals, and rhythms as either individual chunks or parts of larger chunks. Good readers develop the ability to recognize groups of notes as chunks of memorable patterns and gestures rather than individual bits of information, which allows them to take in more musical information at once. Chunking allows good readers to more quickly comprehend the information that they are seeing on the page, relate it to their existing mental representations, and translate it into playing.

Creating Chunks with Declarative and Procedural Memory

How does a performer create musically and physically significant chunks? One method is to use analytical tools to create meaningful groups from memorable harmonies, intervallic relationships, or other patterns. In this passage from the fourth movement of Lukas Ligeti's *Thinking Songs*, chunking can be used to break the excerpt down into meaningful groups.

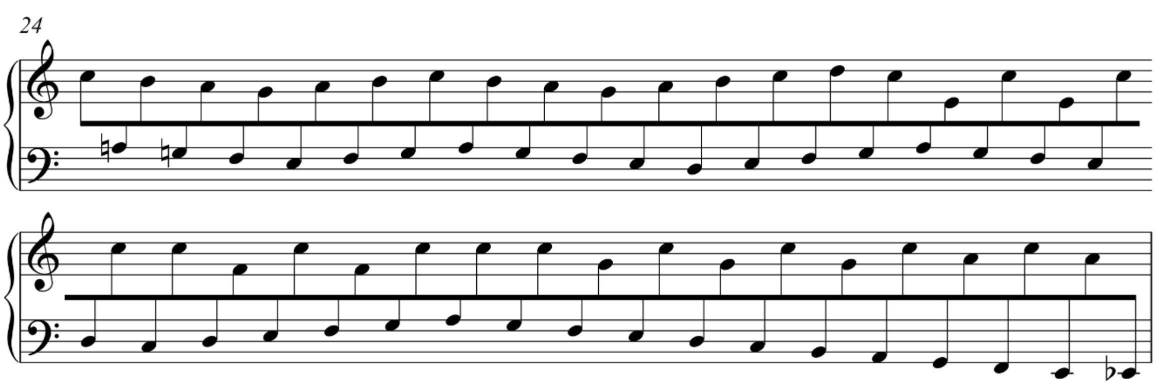


Figure 18. Lukas Ligeti, *Thinking Songs*, IV. Scherzo, mm. 24

This passage contains very similar gestures aurally and visually and the patterns of when the pitch direction changes do not always match between the upper and lower staves, making it difficult to keep track of mentally. Additionally, because the passage is played entirely on the natural keys of the marimba, physical memory is less distinct. Chunking can make performance of this passage more consistent by breaking the passage down into distinct groups to make conceptual and physical recall easier. Even if the piece is played with the music, memory is still involved, and chunking will make performance more consistent. Chunking varies between players as what constitutes a "meaningful group" depends on existing mental representations and prior knowledge. If the way the material is chunked makes sense to the individual, many different parameters can be used to group material such as analysis, physical motions, etc. In the notated example below, I have provided six chunks that I used when practicing this passage.

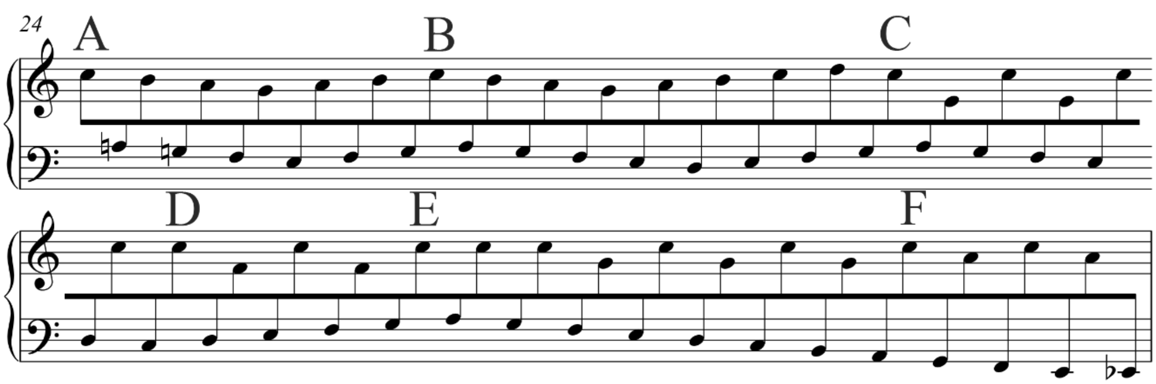


Figure 19. The passage with notated chunks.

I created these chunks by identifying patterns and trying to highlight differences between like material. For example, Chunk A is easily memorable because only a few pieces of information are necessary to remember how it goes. The first detail to notice is that the voices travel only by step and that the intervals between the top voice and the bottom voice are always a major or minor third. Both voices descend and change direction at the same point. Knowing these details separates this chunk into two smaller chunks of material: descending and ascending.

Figure 20. Chunk A divided into two smaller chunks.

Because it is known that the voices only travel by step and that the hands are always a third apart, the only details that must be remembered are the highest (C and A) and lowest pitches (G and E). With practice these two chunks can be assimilated into one larger group of motions and made into one chunk. The reason why I chose to think of this chunk as one group and not two smaller groups is because in my interpretation I hear them as one musical chunk, even though physically and visually it can be thought of as two.

Chunk A and Chunk B are very similar which could potentially make it difficult to distinguish between them. However, highlighting the differences between the two chunks, or the *switch* referred to in the chapter on retrieval practice, can make these chunks more unique and thus more meaningfully chunked. For example, in Chunk B the top voice descends from C again to the same low point, G, but the bottom voice descends one whole step further, to D, before it changes direction and ascends. In this case, this D is the *switch* that distinguishes between Chunks A and B. Practice should be done to make sure that the retrieval of this switch is consistent and accurate. Interleaved practice can be helpful when practicing similar chunks as more cognitive effort must be expended to play each chunk correctly. As a result, the relation between the two voices changes at that point—from being thirds apart to being fifths apart. For the voices to return to where they started (C and A), the upper voice must travel up to D before changing descending once again so that the lower voice can return to A. I choose to begin Chunks A, B, and C where both voices play their original pitches because the repeated material is musically significant in my interpretation and each return to the original pitches signals a change in the next chunk.

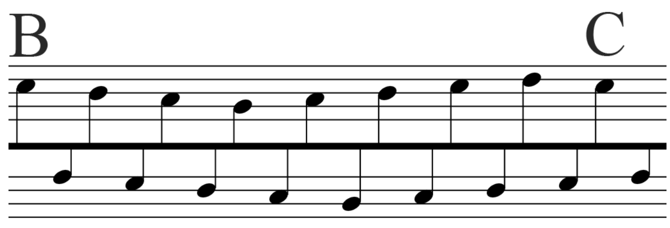


Figure 21. Chunk B and the beginning of chunk C.

I used similar criteria of pattern recognition for the next few chunks. For example, the top voice of chunks C, D, E, and F contains an intervallic leap and each successive chunk's leap is a smaller interval by step. For example, Chunk C leaps between C and E, Chunk D leaps between C and F, and so on. Each of these leaps creates a distinct feeling analytically, musically, and physically. The lower voice continues to move only by step so identifying distinct points in its range assists with chunk creation. In Chunk C, the lower voice descends from A to E. In Chunk D, it ascends from F to A. Chunk E begins again with the same pitches (C and A) as Chunks A, B, and C. Starting at Chunk E, the lower voice moves purely by descent. In Chunk E, the lower voice covers a span of an octave and in Chunk F it descends from G stepwise and ends with a break in the pattern by ending on an accidental Eb). These chunks could be organized in various ways and the material might make more sense to someone else with the material distributed differently between chunks.

Using Varied Practice to Develop the Skills Needed in a Chunk

Isolating these chunks allows an easier time identifying potential issues to be practiced. For example, since the voices in these chunks move in patterns that sometimes coincide and sometimes conflict with one another, it may be difficult to play and track the voices independently of one another. In a passage such as this, it is easy to get physically and conceptually confused. Chunking serves as a particularly potent tool for percussionists as they must often look at their instruments, which can strain cognitive resources. By grouping motions into larger chunks, percussionists can decrease their cognitive strain and leave more attention open for expressive and musical nuances.

Varied practice can be used to develop the physical and conceptual skills necessary to play the chunk. This can be accomplished by breaking a chunk into its component parts (or sub-chunks), practicing each part individually, and then reassembling. In this excerpt, one could choose one voice to play as written while playing an unrelated pattern in the other voice to develop the ability to track voices independently, conceptually, and physically. This is an intermediary step between playing the two voices as written and this exercise makes sure that conceptual skill behind the passage is being practiced and the combinations of pitches are not being memorized by rote, which would be less durable in long-term memory because it does not develop a nuanced mental representation of the passage or the skills behind the passage. Additionally, creating a variety of exercises that are like the passage results in more cognitive effort and thus deeper learning.

By practicing one part of the chunk as written, that voice can become an effective retrieval cue that will be unaffected by mistakes during performance. If a mistake is made, the retrieval cue has been solidified to recover. In the following exercise, the right hand (the upper voice) plays the written pitches of Chunk B while the other voice moves in a distinctly unrelated pattern, in groups of three.

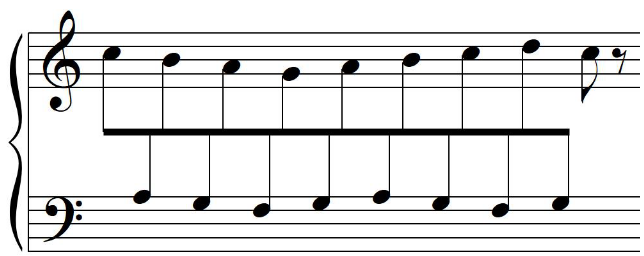


Figure 22. An exercise where the top voice plays chunk B while the bottom voice plays an easier variation on the passage.

The difficulty of exercises can be scaled by altering the parameters of the exercise. If the exercise is too difficult and cannot be overcome, then practicing it will result in few benefits. However, if the difficulty of the exercise is just out of current ability, this will produce greater learning if the difficulty can be overcome. The difficulty of this exercise can be varied by changing what happens in the voice that is not playing the chunk as written. If this exercise were too difficult, the exercise could be remade by only changing the pitch in the lower voice after the upper voice changes direction.

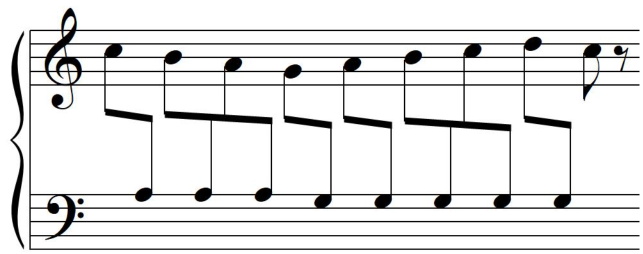


Figure 23. An easier variation of the previous exercise.

To make the exercise more difficult, the lower voice can operate in a more complex way. In the exercise below, the upper voice plays Chunk B while the lower voice repeats notes at random points, which will challenge the skill of playing the voices independently. Making exercises that are more difficult than the actual music makes it easier to play the music as written during performance as it will be situated well within current skill levels.

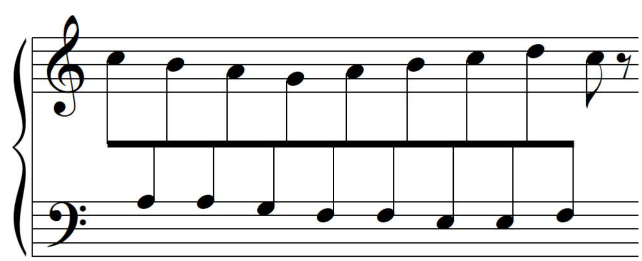


Figure 24. A more difficult variation of the original exercise.

Using Chunking to Learn New Material Quickly

Dividing material into musically meaningful but temporally short groups speeds up the encoding process. During first exposure to new material, encoding can be strengthened by analyzing the music to identify declarative details such as patterns, chord progressions, scalar fragments, etc., and creating chunks early in the encoding process. Chunking in this way is effective and makes encoding more meaningful because it connects the newly developing mental representation of the new material with existing mental representations. In the following passage from Luciano Berio's *Linea*, a dense collection of pitches can be recontextualized as a string of musically simple units.[83]

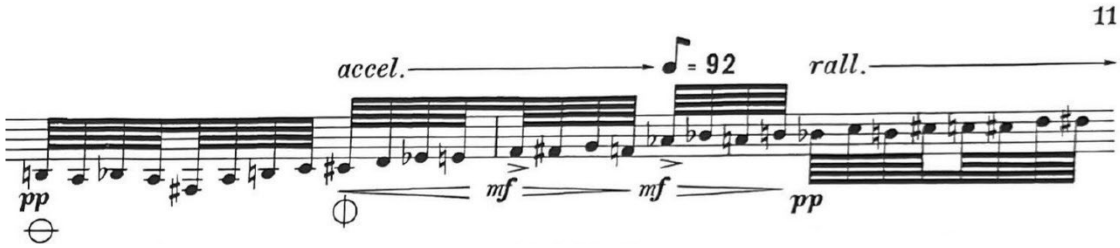


Figure 25. Luciano Berio, *Linea*, p. 11, fragment of measures 1 and 2.

Taking a closer look at the passage shows that it is made up almost entirely of fragments of an ascending chromatic scale that is momentarily interrupted by other ascending material. Identifying that the run mainly consists of a chromatic scale makes it easier to create chunks of those fragments as it relates the material to existing mental representations that contain relevant declarative and procedural memories, providing that the learner has experience playing and thinking about chromatic scales in similar contexts.

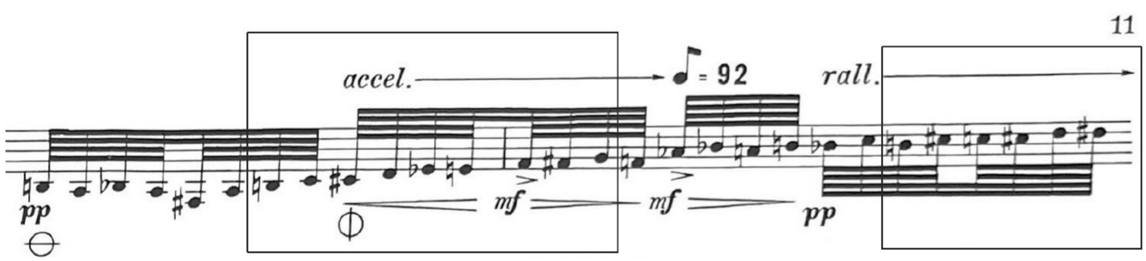


Figure 26. Chromatic material in Berio's *Linea*.

[83] Luciano Berio, *Linea,* (Milan: Universal Edition, 1973), p. 11.

Identifying that the passage contains substantial fragments of a chromatic scale makes the pitches of those fragments easier to chunk and to remember. However, creating chunks of the chromatic material also assists in learning and remembering the non-directly chromatic material because it is more meaningfully distinguished from the other material. Once the material is configured as a set of chunks, these units can be integrated into varied practice sessions and the skills within the chunks (playing chromatic scales) can become targets for warm up material.

Because it is parameter agnostic, chunking is a powerful learning strategy. In addition to parsing musical material by pitch, musicians might create chunks from discrete physical motions. Berio's phrase can also be split into larger groups of physical motions demarcated by dynamics.

Figure 27. Chunks focused on physical motions, demarcated by changes in dynamic.

The first chunk must be played quickly and quietly. The second chunk consists of both a crescendo and a decrescendo (although there is also a case for chunking the crescendo and decrescendo separately) with an accel. The third chunk is the shortest because of a sudden leap in dynamic up to mezzo forte with a quick decrescendo. The fourth chunk is similar to the first. By grouping the material using dynamic as the primary material, a motor program can be developed that takes both pitch accuracy and phrasing into account.

Chaining

Chunks may also be "unchunked" and 'rechunked" through a process called chaining. Chaining involves choosing a chunk of music and practicing it additively, one note at a time. Consecutive material is slowly added and practiced until the chunk is complete. The chunks from the previous example can be practiced with chaining by selecting an individual chunk and playing the first note, then the first two notes, and so on until the entire chunk is formed. This is helpful because it retains the same motor qualities of the motor program that will be used in performance. In the following figure, the first chunk of the excerpt from *Linea* is transformed into a series of chains.

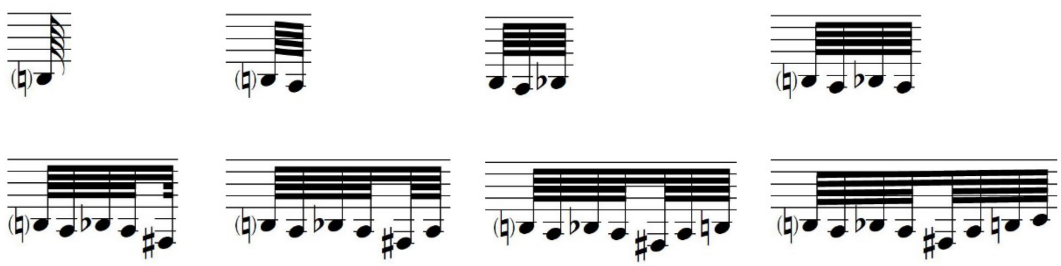


Figure 28. An example of chaining using the first chunk from the Berio fragment.

Linking chunks together additively is another application of chaining. One way to do this would be to repeat the first chunk a few times, fix errors if any arise, then practice the second chunk, then combine the two, then add the third chunk, and so on. Practicing in this way also strengthens the retrieval cues for each chunk as it ensures that the player can start at any chunk and not only at the beginning of the passage. This also provides ample opportunity for interleaved practice. The chunks can be interleaved individually then chained together in groups of two or three chunks and then each larger group of chunks can be interleaved while additively chaining to the whole passage. In the example below, the first chunk is repeated by itself, then chained to the second chunk, then the first three chunks are chained together, and so on.

CHAPTER 8

CASE STUDY NO. 1

Lukas Ligeti, Thinking Songs movement III, Four-Part Invention measures 1-6.

In this section, I deploy chunking and varied practice to efficiently learn and refine a challenging work for solo marimba. I explore Lukas Ligeti's *Thinking Songs*, but almost any piece of repertoire can be used. In this example, I use chunking and varied practice to learn, memorize, and improve accuracy in the passage.

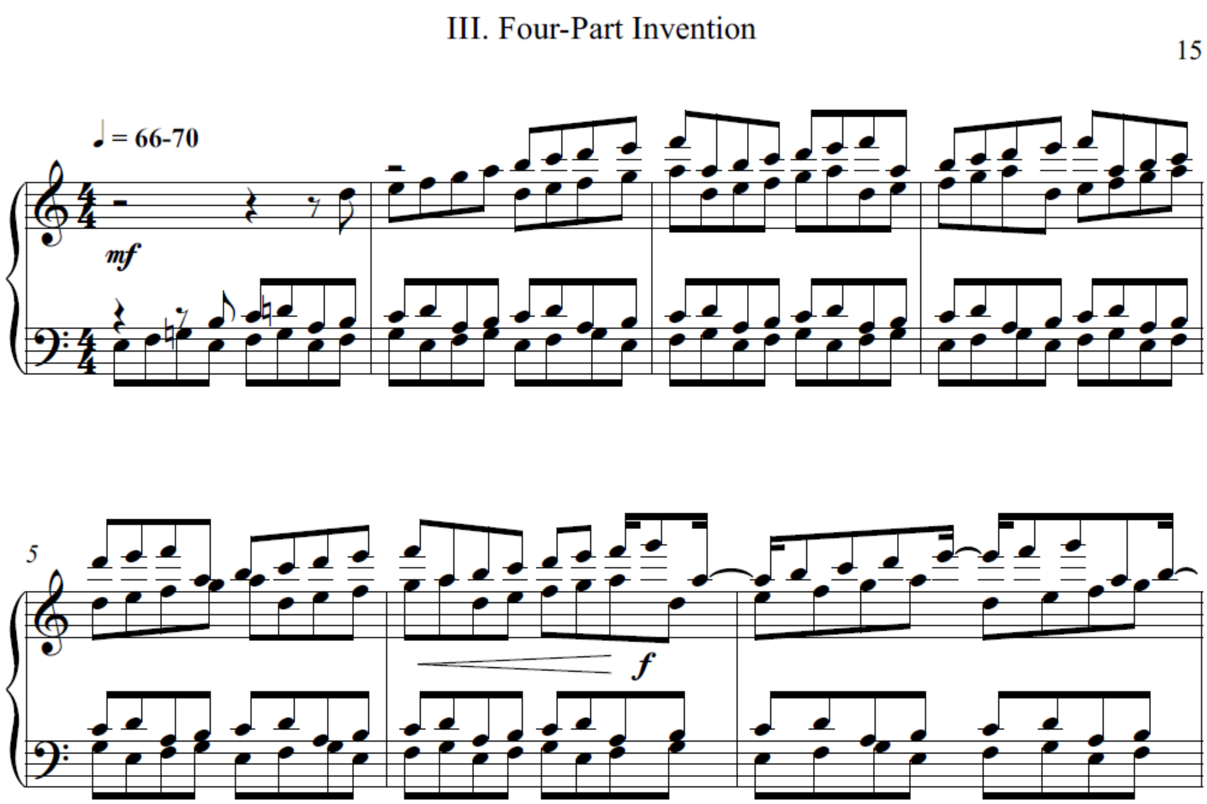


Figure 29. Lukas Ligeti, *Thinking Songs*, III. Four-Part Invention, mm. 1-7.

One reason that this passage is difficult is because of its conceptual complexity. Each voice in the invention has its own pattern that repeats after a different duration: The lowest voice repeats after three eighth notes, the tenor voice repeats after four eighth notes, the alto voice repeats after five eighth notes, and the soprano voice repeats after six eighth notes. Keeping track of the pattern of each voice presents a difficult mental challenge for the performer, and because of its repetition the passage lacks distinct aural checkpoints. As a result, the passage is difficult to learn and resists memorization. It is also difficult to perform while reading the music because of its technical difficulty and the mental effort involved in keeping each process distinct.

In addition to musical difficulties, this passage presents tremendous technical challenges. One notable difficulty arises from the combinations of patterns in each of the voices, resulting in challenging interval shifts throughout the passage. An interval shift refers to the physical movement that must occur in a marimbist's hand between playing different consecutive intervals. For instance, in measure three, the right hand must shift from a fifth to a tenth to a fourth. Widening or narrowing the interval between the two mallets in each of the marimbist's hands while playing requires deft technique. As such, this passage's frequent changes require technical virtuosity from the player. Additionally, the passage is written with no accidentals and is played entirely on the natural keys, which increases difficulty as there are fewer distinct physical and visual waypoints to use for motor chunking.

To play this passage, one must develop the ability to keep track of the independent processes happening in each voice. One way to do this would be to memorize the vertical alignment of each voice through mass repetition; however, this strategy does not leverage the potential of chunking and will result in an impoverished and non-hierarchical mental representation of the passage. Instead, it is much more effective and beneficial for learning to identify and develop the skills behind the passage: creating effective chunks and the ability to play simultaneous patterns of different durations and independent phrasing.

Developing the Ability to Play Independent Processes

Chunking and varied practice are effective means of developing independence between musical voices. For example, the pattern of each voice can be practiced individually to build stability, and then practice can be done to keep that pattern stable while playing something unrelated in another voice to mirror the challenge of the passage without immediately making it overly difficult by attempting to play the passage as written. For this example, the bottom voice (seen in Figure 30) will be practiced first. Practice those three notes, E-F-G, until they feel as if they can be played as a chunk, physically and mentally. After the lowest voice is stabilized, another voice can be added. To keep things distinct, it is helpful to add one of the right-hand voices. However, instead of playing its full pattern, play only the first three notes—D, E, and F—to develop the ability to keep track of different pitches without yet introducing the complexity of overlapping patterns of different duration, seen in Figure 31. Emphasis can be added each time a pattern restarts, to highlight the interactions between the voices and develop the ability to hear and think about them independently.

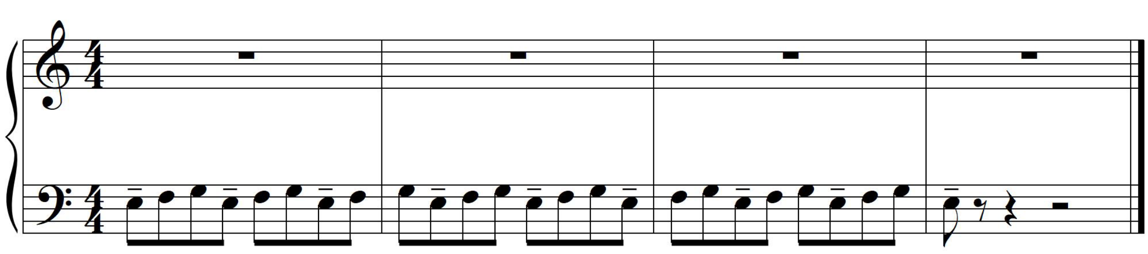


Figure 30. The bottom voice extracted from the passage, with emphasis on E.

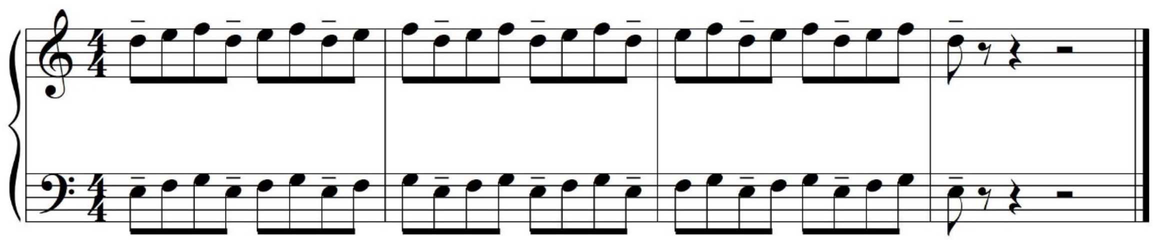


Figure 31. An exercise of the bass and alto voices playing unison groups of three eighth notes.

Varied practice can be employed by creating exercises that change the duration of the pattern in the upper voice. While practicing these variations, care should be taken to notice how these different rhythmic patterns interact with one another. Developing an understanding of how these different rhythmic patterns interact helps the player note important vertical alignments, establishes hierarchical mental representations, and assists in creating effective mental and physical checkpoints to function as retrieval cues during performance.

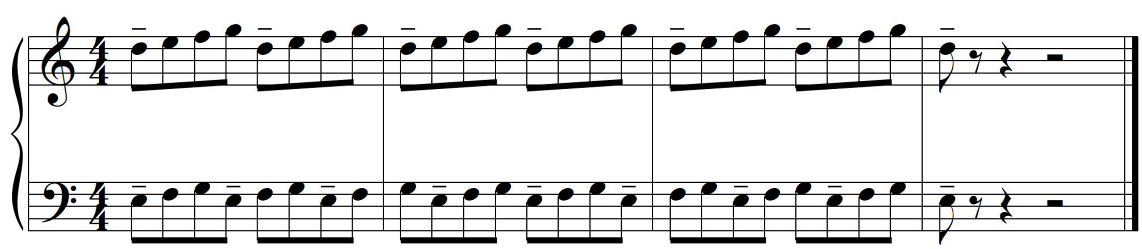


Figure 32. An exercise playing a four-note pattern in the top voice against a three-note pattern in the bottom voice.

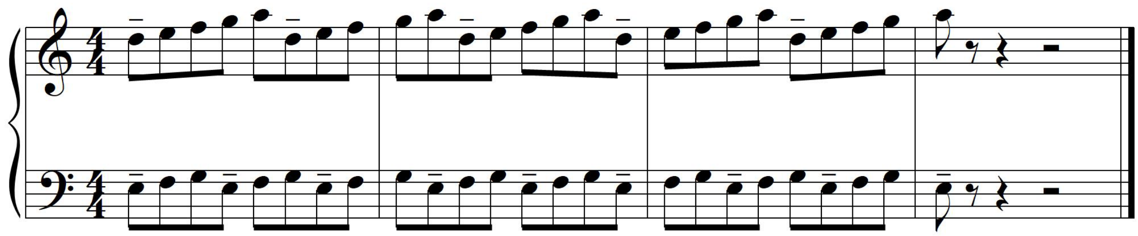


Figure 33. An exercise playing a five-note pattern in the top voice against a three-note pattern in the bottom voice.

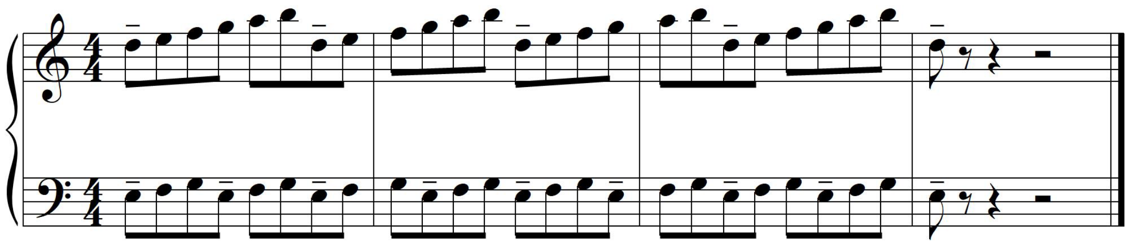


Figure 34. An exercise of playing a six-note pattern in the top voice against a three-note pattern in the bottom voice.

Chunking One Hand

The previous exercises developed the ability to keep track of independent simultaneous patterns between voices. After this skill has been developed, creating and practicing chunks of the passage bridges the gap to playing the passage as written. In the next example, I have re-notated the composite pattern of the voices in the left hand and separated the material into four chunks (labeled A, B, C, and D) that each have a duration of three eighth notes. Each chunk begins when the lowest voice returns to E and repeats its pattern. This is effective as the lowest pitch is aurally and physically distinct. To make the voices musically independent, I emphasize whenever the bass voice plays E, and when the tenor voice plays A. Additionally, the figure illustrates the different intervals contained within each chunk.

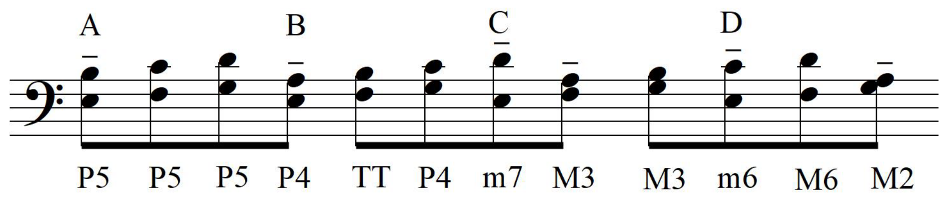


Figure 35. An analysis of the intervals contained in the chunks.

Chunk A is made up entirely of parallel ascending perfect fifths, which makes it quite easy to remember. The second chunk is made up of a perfect fourth followed by a tritone followed by another perfect fourth. The intervals of Chunk B are one step smaller than those of Chunk A. The third and fourth chunks are more complex as the intervals vary more frequently within chunks. The third chunk begins with a seventh and then two thirds, and the fourth chunk begins with two sixths and then a second. Both chunks contain two of the same interval and a single (seemingly unrelated) interval. However, the two chunks are related to one another because their combination of intervals are inverted from one another. The third chunk contains a single interval followed by two of the same (1+2), and the fourth is the opposite (2+1). Knowing the relationship between the chunks improves the depth of mental representations surrounding them and will make it easier to commit the chunks to long-term memory.

Additionally, the intervals contained in chunks C and D are complementary to one another. The combination of a second and a seventh makes an octave, and so does the combination of a third and a sixth. Knowing these analytical details provides more context for the pattern and makes it easier to learn and to commit to memory. The overall composite pattern of the two voices together represents every interval between a second and a seventh, and no specific collection of pitches is repeated. With practice, the four chunks will be assimilated into one chunk, physically and conceptually.

Using Varied Practice for Technical Development

After the left hand is stabilized, begin to add in material in the right hand. The technical difficulty here is twofold as some of the interval shifts are quite difficult and can affect accuracy while maintaining the pattern in the left hand. Before attempting to play the passage as written, varied practice can be used by making exercises that work on the technique in similar ways to how it appears in the passage. One way to do this is to select one of the chunks from the left hand and practice ascending intervals in a different duration in the right hand. In figure 36, the left hand plays Chunk A while the right hand plays ascending sixths in a pattern that repeats every five eighth notes (the length of the alto voice's pattern).

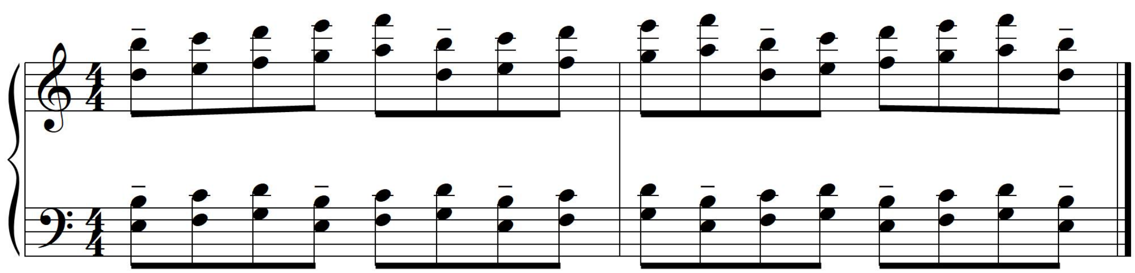


Figure 36. An exercise playing sixths in the right hand while the left hand plays chunk A.

While this exercise centers on the interval of a sixth, incorporating a variety of intervals can lead to a more comprehensive and holistic approach to technical development. Sample variations include changing which interval the right hand plays, changing where the right hand begins in relation to the left hand, changing which chunk the left hand plays, or playing the entire left hand pattern. The exercise below shows the right hand playing sixths while the left hand plays its entire pattern.[84]

Figure 37. An exercise playing sixths in the right hand while the left hand plays all four chunks.

The next examples highlight a few of the myriad variations possible with this exercise. In figure 38, the left hand stays the same while the right hand plays seconds, then thirds, then fourths, and so on every time returns to D. In figure 39, the right hand plays its written pitches, but in a varied rhythm while the left hand repeats its pattern with no changes in rhythm. Practicing in this way results in a deeper understanding of technique and increases overall fluency on the instrument. Varied practice can also be used to target specific difficulties in the passage, such as in Figure 40, where the right hand repeats a difficult interval shift while the left hand continues to play its pattern.

[84] Note that the pattern would extend farther than I have notated as it would take five repetitions of the five-note long pattern before both hands return to where they started. This is true for the following examples as well.

Figure 38. An exercise of the right hand playing a variety of intervals while the left hand plays all four chunks.

Figure 39. An exercise of the right hand playing its part in varied rhythm while the left hand plays all four chunks.

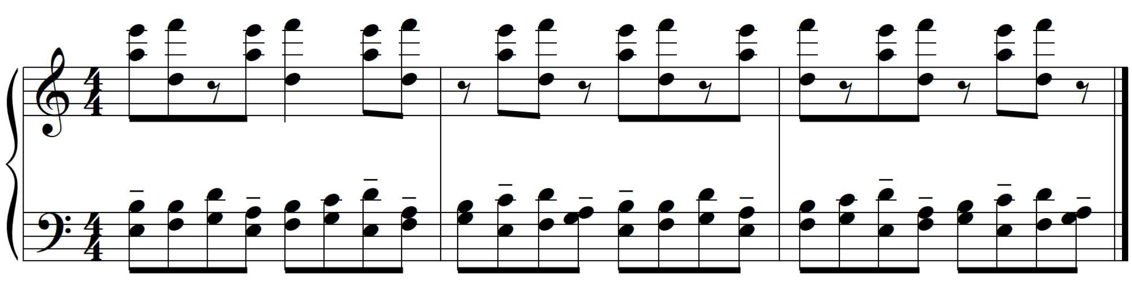


Figure 40. An exercise of the right hand repeating a difficult interval shift while the left hand plays all four chunks.

Because of the importance of varied practice for musical learning, it is essential that musicians develop their own ability to generate exercises based on the repertoire they are playing. If a player is comfortable with generating variations and exercises based on the music they are playing, they enrich their understanding of the material and improve the musical, conceptual, and technical skills that underlie the material. The possibilities for exercises such as these are endless and are especially useful for when technical development has plateaued in a specific passage. Varied practice is also useful to increase the challenge of repertoire already known well, resulting in higher-quality mental representations.

Varied practice is highly individualized and relies heavily on the context of one's own learning. The approach one may take to varying practice and creating chunks will differ from player to player based on their existing mental representations, prior experiences, and current musical and technical development. Moreover, a single player's approach may differ over the lifecycle of learning a piece by a single player, as new information and experiences continually reshape their learning strategies.

CHAPTER 9

CASE STUDY NO. 2

Jacques Delécluse, Étude no. 9 from *Douze Études pour Caisse-Claire.*

In Ligeti's *Thinking Songs*, the performer is challenged to develop varied practice strategies to address motor and conceptual chunks primarily associated with pitch. These strategies are also well-suited to music of a primarily rhythmic nature. The next case study examines an excerpt from Étude no. 9 in Jacques Delécluse's seminal collection of snare drum etudes, *Douze Études pour Caisse-Claire.*[85]

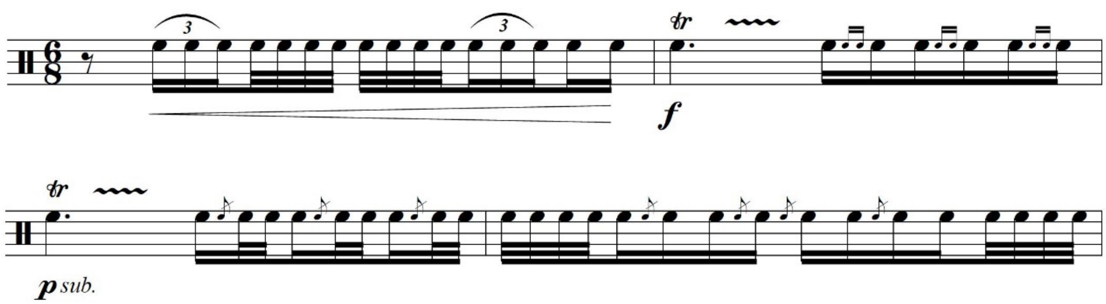


Figure 41. Jacques Delécluse, Étude No. 9 from *Douze Études pour Caisse-Claire*, mm. 13-20 (Re-engraved by Tony Kirk).

Here, the excerpt's dense technical challenges—sudden dynamic shifts, transitions in and out of rolls, placement of grace notes during fast rhythms at both loud and soft dynamics—provide for a clear opportunity to mobilize chunking and interleaved practice.

[85] Jacques Delécluse, Étude No. 9 from *Douze Études pour Caisse-Claire*, mm. 13-20, Paris: Éditions Musicales Aphonse Leduc, 1964.

Creating Chunks from the Excerpt

In the example below, I have broken the excerpt down into several chunks based on physical motions, to me the most meaningful delineation of musical material in the passage.

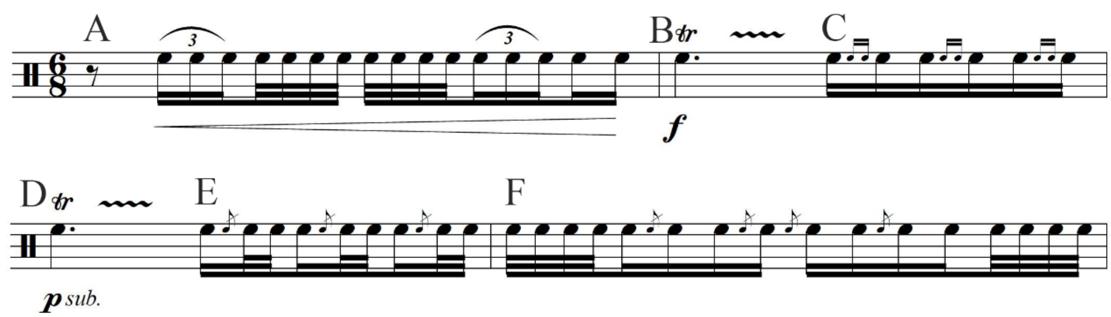


Figure 42. The excerpt separated Into motor-focused chunks.

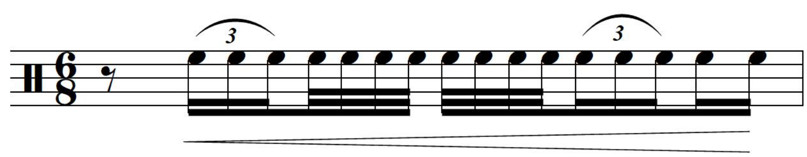
Each chunk is technically distinct and is situated at points where the primary technical demand of motor movements changes. Delécluse's etudes require the performer to transition smoothly between a variety of techniques, and separating the etude into chunks that are demarcated by changes in technique allows them to be practiced separately without losing relevance to the whole. It is helpful to group similar physical motions together so that they can be practiced conceptually and physically as one big motion that includes many small motions, even if the length of each chunk varies. Chunking also allows for the development of robust mental representations as it becomes clear to see similarities and differences between chunks. For example, Chunks B and D are both rolls of the same duration, but at different dynamics, while Chunks C, E, and F have similar technical demands.

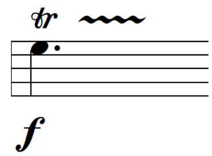
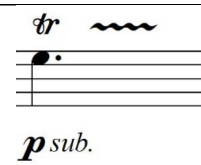
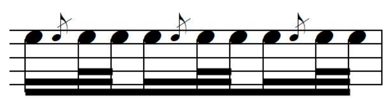
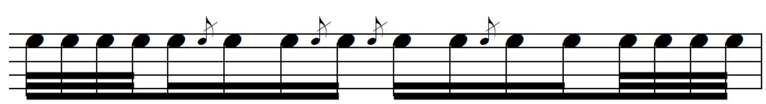
Mental Representations, Goal Setting, and Interleaved Practice

Interleaved practice can easily become mindless if mental representations and specific goals are not determined before practice. In addition to forming a musician's approach to thinking about music more generally, mental representations shape a player's concept of what an idealized performance of a given piece of music sounds or looks like. Practicing is the act of identifying and rectifying discrepancies between one's mental representations and one's current level of performance. Goals serve as guides for players to develop their current performance towards their idealized mental representation. By developing high-quality and specific mental representations, players can critically think about and dissect musical, technical, and mental issues in chunks and set goals accordingly.

Goals vary from player to player based on many factors such as interpretation, current skill level, and existing mental representations, but they should be specific so that feedback and observations between practice attempts can be used to adjust accordingly. In the table below I have listed musical goals that inform my own practice of these chunks:

Table 4. Individual chunks and associated goals.

Chunk	Music
A	 Smooth crescendo, rhythms correct, no accents.

B	 Consistent dynamic throughout the roll, even hand speed, not accenting the beginning or end of the roll. Start and end the roll using the right hand.
C	 Keeping grace notes low to the drum and tight to the beat, make sure not to slow down, consistent dynamic.
D	 Start the roll with the left hand and end on the right hand. Even hand speed. Clean articulation to end the roll.
E	 Make sure that the grace note is heard but doesn't affect the quality of the rhythm. Make sure not to accent the start of each 32nd note grouping.
F	 Make sure that the rhythm is not affected by the grace notes and that the quality of articulation, clarity, and sound quality is not changed by the quickness of the passage.

It can be cumbersome to write out each goal every time that something is practiced, but detailed mental representations and interleaved attempts at the material allow the ability to continually retrieve these goals and strengthen mental representations between practice attempts. Additionally, clear goal setting prevents the player from feeling lost and confused every time a task is returned to using interleaved practice and ensures engagement with mental representations as opposed to mindless repeating of the passage.

Using Interleaved Practice to Practice Chunks Individually

Now that that the excerpt is chunked, each chunk can be practiced with interleaving. One way to interleave practice of these chunks is to practice each chunk for a few minutes in a random order and then repeat the practice of chunks again in a different order. Practicing each chunk for a short amount of time and in a random order ensures that massed practice—which is less cognitively demanding, resulting in weaker retention—does not give the illusion of mastery. Additionally, it allows more "first attempts" of material, which is what matters most in live performance. Alternatively, instead of practicing a different chunk every few minutes, the chunk being practiced can be changed every few repetitions. However, this requires more detailed mental representations as there will be less time to engage in deep thinking about the chunk. This is helpful if the mental representations are already quite clear and improving physical execution is the main goal. Material that is already well-learned and stable in long-term memory can be interleaved more frequently.

Using Interleaved Practice to Chain Chunks Together

Another strategy to improve this excerpt is to chain multiple chunks consecutively, but practice different combinations of chained chunks in interleaved fashion. Even when the chunks are mastered in isolation, linking them together will result in some changes to physical execution. For example, Chunk B is seemingly simple by itself as it is just a roll at a single dynamic but playing it in context by surrounding it with Chunks A and C makes it more difficult due to the changes in technical demands (the motor program) between chunks.

Chaining consecutive chunks makes sure that the execution is stable between transitions. It also has the added benefit of maintaining the musical context of the phrase. It is also helpful to make sure that there is overlap between different combinations of chunks. For example, instead of just practicing A and B together, C and D together, and E and F together, practice A and B, B and C, C and D, D and E, and E and F. This ensures that practice accounts for each transition between chunks and no moments of change in the motor program are overlooked. See the examples below for these combinations:

Figure 43. Combinations of adjacent chunks.

Interleaved practice can be used for these different combinations. However, because the context of each chunk changes with the addition of a consecutive chunk, mental representations must be updated with new goals and new observations as the motor program will change slightly with the addition of consecutive chunks. Thinking deeply about what changes between different combinations of chunks helps develop comprehensive mental representations about playing this passage and playing snare drum in general, resulting in more overall learning that transfers beyond this specific application. Additionally, chaining chunks informs practice of isolated chunks to be more effective as the chunks can be practiced independently with the context of the whole phrase kept in mind.

To take chaining a step further, chains may be constructed from three adjacent chunks. This ensures that each chunk is surrounded by the chunk that precedes and the chunk that follows it. The combinations of chunks should still maintain overlap. For example, Chunks ABC, BCD, CDE, and DEF can all be practiced. Interleaved practice can then be used to alternate between practice of these different combinations.

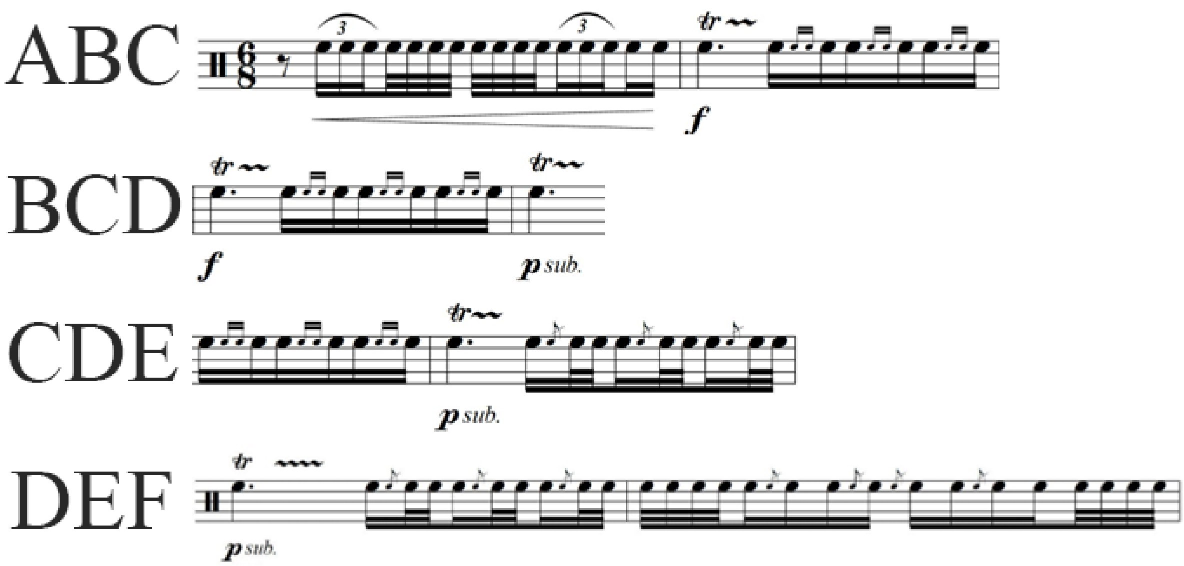


Figure 44. Combinations of three adjacent chunks.

The chunks can continue to be chained until the whole excerpt is played. Additionally, repetitions of the whole excerpt can be folded into practice of the chunks. This is helpful to keep the entire phrase in mind and test performance even when individual chunks or combinations of chunks are still being practiced. Interleaving the whole excerpt during practice can also highlight spots or issues with the passage that are being overlooked or do not become apparent until the excerpt is played in its entirety. This strategy makes sure that the excerpt is not repeated in full to the detriment of working on specific skills, but also makes sure that each skill can be applied in context.

Troubleshooting Interleaved Practice

Although interleaved practice promotes more durable learning than massed practice, its use should not be so complex that it prevents engaging with mental representations and specific goals. Feedback from practicing must be used to adjust practice strategies in real-time. In this example, each chunk was only practiced for a few minutes, but the time length should be adjusted based on a variety of parameters. For example, if an individual finds that Chunks C, E, and F, are much more difficult than A, B, and D then there is no reason why they must practice them all for the same amount of time. Instead, they may realize that Chunks A, B, and C are only difficult in combination with other chunks, and so they may decide to only practice them in the context of chained groups of chunks, so they do not waste any time on skills they already have developed.

Additionally, if interleaving is done using time lengths that are too short, then it is possible that it may hinder encoding new information and updating mental representations. Learning requires paying attention to details and thinking critically. If the time segments are too short and provide no space for thinking, then learning will not be as effective. Interleaved practice is especially effective for training for performance of material that is already known well, but if material is still in the encoding phase, then there must be enough time to think and experiment while practicing so that mental representations are formed and refined.

Varied practice can easily be incorporated into an interleaved practice schedule by breaking down the excerpt into its component skills and writing, improvising, or selecting existing exercises to work on those skills within the interleaved periods. For example, the excerpt's main difficulties are the transitions in and out of rolls and playing the grace notes at a quick tempo. Therefore, exercises or etudes that highlight these skills can be selected rather than only repeating the exact material in the excerpt. Of course, the excerpt must be practiced as written to make sure that it can be performed consistently and to work on phrasing, but the skills necessary to play the passage can be developed faster, more effectively, and with more transferability by working on exercises that not only target the skill itself but other skills that are similar.

CHAPTER 12

CONCLUSION

In this work, I explored learning concepts such as deliberate practice, mental representations, the stages of memory, and desirable difficulties. Additionally, I discussed specific research-based learning strategies such as retrieval practice, spaced repetition, interleaved practice, varied practice, and chunking. Throughout, I interpreted these concepts and strategies, explained their relevance to musicians, and presented applications for musical practice.

My hope is that this work demystifies the learning and memorization process and offers performing musicians concrete, specific, and actionable steps to incorporate the most effective learning strategies into their practice. As such, my goal is that any musician who reads this document can understand and apply the information that it contains to their practice.

Limitations of My Research and Future Considerations

There are a few limitations to my research. First, it focuses on examples from percussion repertoire and as such, my examples may target problems that disproportionately concern percussionists or are less immediately applicable to other instrumentalists or vocalists. For instance, many of the examples I use address musical material with multiple voices. Musicians who play instruments that are only capable of a single line may find these applications less relevant. However, this narrow focus on only a few pieces of repertoire helps keep the strategies targeted, reduces the need for extensive percussion repertoire-specific knowledge, and serves to illustrate that the same passage of music can be practiced using a variety of the strategies I present. Additionally, the applications of these strategies and the choices of examples are limited by the need to communicate through written explanation and visual examples. Exploring other formats, such as video tutorials and examples, could be beneficial in demonstrating strategies more quickly and accessibly, without relying solely on written content.

Furthermore, my research draws heavily from existing studies, many of which focus primarily on non-musical activities. However, the efficacy of these strategies has been proven across a variety of domains and I believe that my interpretations and applications of them to musical practice are accurate and practical. Future work could involve testing these strategies on a variety of musicians over an extended period using specific quantitative measures, although implementing such experiments could present challenges, such as controlling for learning contamination, accounting for differences in the demands for different instruments, and developing non-subjective measures to assess skill level.

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APPENDIX A

HANDOUT SUMMARIZING LEARNING CONCEPTS AND STRATEGIES

THE CONCEPTS:

Deliberate Practice:

A type of practice that includes regular meetings with established experts, well-defined goals, effective practice strategies, and feedback loops that allow the learner to adjust between practice attempts.

Table A1. Naïve, purposeful, and deliberate practice.

Type of Practice	Description of Practice	Musical Example
Naïve practice	No clear goal and no effective strategy. Not knowing what to practice or how to practice it.	I will practice this piece today.
Purposeful practice	Semi-Clear to Clear Goal, maybe using an effective strategy. Having an idea of what to practice and how to do it but may not necessarily be the best way to practice it.	I will improve the beginning of this piece by using slow practice.
Deliberate practice	Very clear goal, using an effective strategy. Knowing what to practice, and how to practice to attain the desired result.	I will improve the opening phrase, making it more accurate and consistent, by using interleaved practice to improve consistency, slow practice to clarify memory, and varied practice to increase technical fluency.

Mental Representations:

Cognitive structures that are formed through extensive practice and used to organize or process anything that the brain thinks about, concrete or abstract, in relation to a specific skill, idea, or collection of information.

Table A2. Examples of mental representations.

Skill/Concept/Idea	Details Included in the Mental Representation
Major scales	- Formed by a collection of whole steps and half steps. - Contains a half-step between scale degrees 7 and 1, the leading tone. - Has a certain characteristic of sound, “bright”, “happy,” “full of expectation.”
Snare drum technique	- Grip is approximately 1/3rd from the bottom of the stick. - The first three fingers form a three-point fulcrum. - The sticks should travel in a straight line and strike the same location on the head. - The stroke is primarily achieved with the wrist, but arm and fingers are used in specific situations.
Performing a specific piece of music	- Knowledge of the form of the piece and other structural details. - Interpretive details. - The actual notes, rhythms, and articulations in the piece. - Expressive goals for performance and how to achieve them. - How the piece relates to other pieces.

Stages of Memory:

Table A3. The stages of long-term memory.

Stage of Memory	Description of the Stage
Encoding	Sensory details are noticed and committed to memory. Memory traces of the piece are formed.
Consolidation	Memory traces are strengthened. More details are noticed, and errors are fixed.
Storage	Information addressed in the previous two stages are stored in long-term memory.
Retrieval	The brain reconstructs the various elements of the skill: motor, auditory, visual, kinesthetic.
Reconsolidation	After memories are retrieved, they are recontextualized and connected to any new learning that has taken place.

Desirable Difficulties:

The idea that increasing the difficulty of learning results in better long-term learning, higher quality encoding, and better retrieval. Improvements in performance during training do not indicate effective learning.

THE STRATEGIES:

Retrieval Practice:

A strategy in which a skill or knowledge is actively recalled from memory, rather than passive review or restudy, and because retrieving knowledge from memory is more cognitively difficult, it results in superior learning and retention.

Declarative vs. Procedural Memory:

Table A4. Declarative vs. procedural memory.

Declarative	Procedural
Explicit/Conscious Facts and Details - the piece begins in Eb major, it is in sonata form, etc. Concepts/Ideas - it should sound like ___.	Implicit/Unconscious Cognitive Processes - the ability to transpose to a different key, the ability to read and translate musical notation into physical movement, and so on. Motor Skills - the ability to execute physical movements necessary to play.

Examples: extremely slow practice, active recall using mental practice, the generation effect.

Spaced Repetition:

A strategy in which learning of material or a certain skill is spaced over a longer period of time, opposed to the same amount of practice occurring in a shorter time frame (massed practice). As mastery of material or a certain skill improves, increasing the absolute spacing between practice sessions encourages long-term retention, as it increases the difficulty of recall.

Examples: practicing 2 hours for 7 days > 7 hours for 2 days, introducing space between practice sessions of well-learned material.

Table A5. Sample spaced practice schedule for different types of material.

Type of Material	Session 1	Session 2	Session 3	Session 4
New Material	Practice	Practice	Rest	Practice
Developing Material	Practice	Rest	Practice	Rest
Well-Learned Material	Practice	Rest	Rest	Practice

Interleaved Practice:

A strategy in which practice tasks are frequently alternated between, rather than practicing each task to completion sequentially (blocked practice). This allows the reconstruction of the skill from long-term memory rather than continually refreshing a skill in short-term memory.

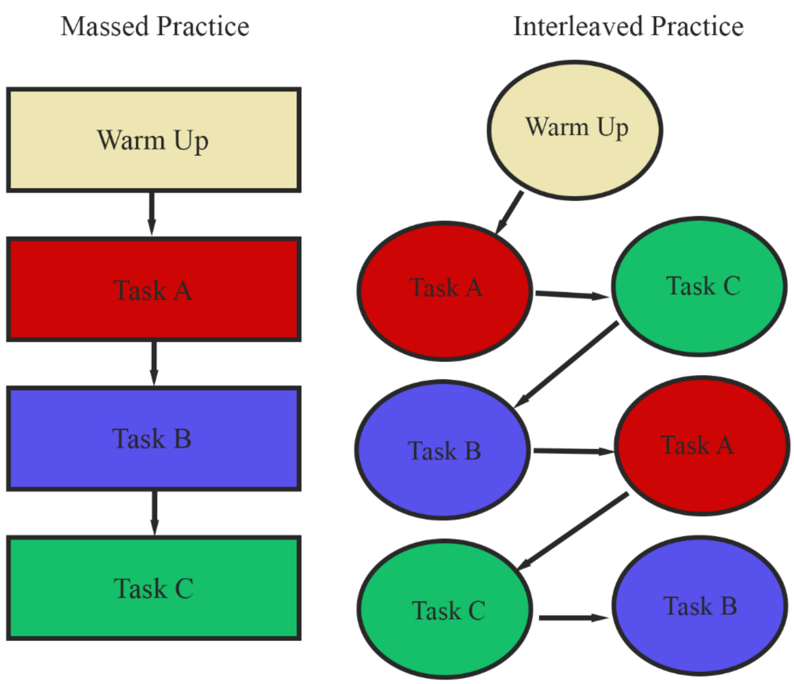

Figure A1. Massed vs. interleaved practice schedules.

Varied Practice:

A strategy in which the practice of a skill is modified in some way, or the conditions of practice are varied. Results in more flexible and robust mental representations allowing greater adaptability and transferability between skills.

Examples: altering the musical parameters of a passage (such as dynamics and rhythms), changing the location of practice, practicing using unfamiliar instruments or different mallets.

Chunking:

A strategy in which individual units of information are grouped into larger and more meaningful groups to overcome the limits of short-term memory. This can be done conceptually, by recognizing patterns and making connections between material, and physically, by grouping muscular movements into larger motions.

Examples: recognizing fragments of scales, using analysis to conceptualize individual material as parts of larger groups and patterns, breaking the physical motions needed to execute a skill into groups of motions