Application of Selected Principles from

Motor Learning Theory to Violin Pedagogy

by

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ABSTRACT

Research in learning has been conducted for decades, and an area that has received increasing attention since the mid-20th century is motor learning. Since then, new theories and experiments have been developed describing principles of motor learning with parameters that can improve or degrade the learning process. These principles have been applied to many different areas such as psychology, language, and especially sports. Although music involves motor skills, only relatively recently have there been attempts to link these scientific findings with music performance. Given the importance of this area, this document seeks to explore ways in which one may apply principles from motor learning theory to music and more specifically to violin pedagogy.

The motor learning principles discussed are based mainly on the studies and theories of Robert Bjork, Cheryl A. Coker, Timothy Lee, Richard Magill, Richard A. Schmidt, and Gabrielle Wulf. The selected topics are focus of attention, practice schedules (discussing blocked and random practice schedules), and variable practice. There are two chapters dedicated to each area. The initial chapter of each topic (two, four, and six) contains a brief literature review that provide a base for application to violin pedagogy. The second chapter of each topic (three, five, and seven) explores those principles along with practical guidelines on how to apply them to violin pedagogy.

While some research and experiments in motor learning support pedagogical approaches already used in music (based on the teacher's intuition and common sense) other studies suggest approaches that are quite counterintuitive. Reviewing a wide variety of practice techniques through a scientific lens provides valuable insights to the field of violin pedagogy and musical performance in general.

DEDICATION

To God, to my wife Mayelle Daum Unglaub,

and to my parents Josiel Unglaub and Tania Unglaub.

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CHAPTER 1

INTRODUCTION

The art of practice has long been the study of serious musicians throughout their careers. Increasingly high standards, competition, and the volume of music to be learned lead musicians to seek solutions as to how to learn more effectively and efficiently while at the same time playing reliably, consistently, and with accuracy and ease. This goal is present not only among musicians but also athletes, dancers, patient rehabilitation, and even in academics at the secondary or college education level. Teachers and educators in any field are constantly seeking ways to deliver information to their students in the most effective way possible for the students to absorb the most information to lead to better learning outcomes.

Research in learning has been conducted for decades, and an area that has received increasing attention since the mid-20th century is motor learning. Since then, new theories and experiments have been developed describing principles of motor learning with parameters that can improve or degrade the learning process. These principles have been applied to many different areas such as psychology, biomechanics, kinesiology, disability and rehabilitation, language, and especially sports. Although music involves motor skills, only relatively recently have there been attempts to link these scientific findings with music performance. Given the importance of this area to music, my document seeks to explore ways in which one may apply principles from motor learning theory to music and more specifically to violin pedagogy.

This document provides a literature review on selected topics from the motor learning research that are relevant to instrumental practice, overviewing its major research, principles, and theories with the intent to apply those principles to violin pedagogy with practical discussions and recommendations. Although many principles and findings from the motor learning literature are of great interest to musicians, there are relatively few studies that make connections between both areas of study, and even fewer that give a practical guide on how to apply principles from motor learning theory to music teaching and learning. Thus, the present research paper is the first of its kind to directly relate motor learning research with violin pedagogy.

The motor learning principles discussed are based mainly on the studies and theories of Robert Bjork, Cheryl A. Coker, Timothy Lee, Richard Magill, Richard A. Schmidt, and Gabrielle Wulf. These researchers have been widely recognized through their writings in this area of research since the 1970s, with highly regarded and accepted theories and experiments in the academic and scientific world. Moreover, the few studies already made in music using motor learning concepts are also considered in this paper.

During the analysis of the existing literature, it was noticed that some findings agree with traditional methods of teaching and practicing music. However, there are many principles that are still new for most musicians. Many theories and experiments suggest approaches that seem counterintuitive and against general common sense; some even disagree with long-held practices and recommendations among musicians. As a violinist and music educator for more than two decades, it struck me that some practice methods we use are in contradiction with scientific findings. This made me eager to research more and to test those findings in my own playing as well as with my students. The results are very significant and of great value not only for violinists but for musicians in general. Thus, the objectives of this research paper are to create a closer connection between research in motor skills acquisition and instrumental practice, give valuable insights to other musicians on how to improve their teaching and practice, question some traditional recommendations from the musical world on how to practice, and expand the discussion on violin and music pedagogy to a relatively new area.

This research paper discusses three intriguing principles: focus of attention, practice schedules (discussing blocked and random practice schedules), and variable practice. There are two chapters dedicated to each area. The first chapter of each topic (two, four, and six) contains a brief literature review and explores the main experiments and findings that provide a base for application to violin pedagogy. The second chapter of each topic (three, five, and seven) includes a discussion of those principles along with practical guidelines on how to apply each of them to violin pedagogy based on the literature review and on my own experience. The literature review is not intended to be exhaustive, but it gathers the most important data and relevant research for the purposes of this paper. The recommendations and suggestions made on the application chapters can certainly be expanded, adapted, and applied to other musical instruments.

The first principle examined in this document, focus of attention, deals with to what the individual is directing their attention when performing a skill. The motor learning literature divides the focus of attention into two categories: internal focus of attention (IF) and external focus of attention (EF).[1] The first happens when individuals direct their attention to their body mechanics and how to move to produce the actions. The second happens when individuals direct their attention to the objects that are being

[1] Richard A. Schmidt et al., *Motor Control and Learning: A Behavioral Emphasis*, 6th ed. (Champaign, IL: Human Kinetics, 2019), Chap. 4, https://redshelf.com/book/1033636/motor-control-and-learning-1033636-9781492586623-richard-a-schmidt-timothy-d-lee-carolee-winstein-gabriele-wulf-howard-n-zelaznik.

manipulated, the effects of their actions, and to that which is external from their bodies. The chapters dedicated to this principle (two and three) discuss which approach produces better learning, provide a classification system of focus of attention applied to violin pedagogy, and offer insights and suggestions on how to use this principle in practicing.

The chapters on practice schedules cover ways in which to effectively organize the repetitions of the different tasks that one intends to practice. Repetition is undoubtedly one of the most important factors when learning a skill. But is there an optimal strategy to sequence all the different tasks to produce more effective long-term learning? Traditionally, music educators and pedagogues recommend repeating the task that needs improvement numerous times, either in a predetermined number or until achieving a criterion level. Only then the learner moves to the next task to be learned. This approach is called blocked practice schedule in the motor learning literature. But what if those tasks were organized in a way that they are not repeated several times consecutively? Rather, what if they are repeated a few times in a row (or even only one time), but in several rounds? For example, if one chooses three tasks to practice (A, B, C) and plans to do six repetitions of each, instead of repeating in a blocked fashion (A-6x, B-6x, C-6x), the learner could perform those same six repetitions using this alternative approach called random practice schedule in the motor learning research (AA, BB, CC, BB, AA, CC, BB, CC, AA, for example). Do these different practice schedules produce different long-term learning outcomes? Chapters four and five discuss the implications of each approach giving suggestions and recommendations on how to schedule the tasks to be learned in violin practice sessions to produce better learning results based on scientific research.

Finally, the principle of variable practice deals with how to repeat the desired task to be learned. Should the task be repeated as similar as possible, with no variation, and under the same conditions to have the best learning outcomes? Does the introduction of variations of the task degrade or improve learning? The chapters dedicated to this topic (six and seven) discuss the effects of variation on learning and provide insights on how to use this principle in violin pedagogy.

Before moving to the exposition, discussion, and application of the selected topics, it is important to overview a critical concept from the motor learning literature. The counterintuitive findings from the motor learning research may conflict with general common sense due to the distinction between learning and performance. While learning can be defined as the "relatively permanent changes in behavior or knowledge that support long-term retention and transfer"[2] or "as the relatively permanent acquired capability for performing some action,"[3] performance refers to the "temporary fluctuations in behavior or knowledge that can be observed and measured during or immediately after the acquisition process"[4] or more simply, "performance refers to the execution of a skill at a specific time and in a specific situation."[5]

This is a very important distinction because any given performance does not always represent what was learned.[6] Sometimes performance may exceed or fall short of

[2] Nicholas C. Soderstrom and Robert A. Bjork, "Learning Versus Performance: An Integrative Review," *Perspectives on Psychological Science* 10, no. 2 (March 2015): 176, https://doi.org/10.1177/1745691615569000.
[3] Richard A. Schmidt, "Principles of Practice for the Development of Skilled Actions: Implications for Training and Instruction in Music," in *Art in Motion: Musical & Athletic Motor Learning & Performance*, Musical & Athletic Motor Learning & Performance. (Peter Lang GmbH, 2009), 43.
[4] Soderstrom and Bjork, "Learning Versus Performance," 176.
[5] Richard A. Magill, *Motor Learning and Control: Concepts and Applications*, 8th ed. (Boston: McGraw-Hill, 2007), 257.
[6] Soderstrom and Bjork, "Learning Versus Performance," 176.

what was really learned. What violin student has not experienced practicing hours on a passage and achieving a new level of mastery by the end of the session, just to go back to the practice room the next day and feel like the mastery gained from the previous day's session was lost? Another scenario is a violinist who was well prepared for a particular concert after having previously performed a work successfully multiple who then suffered multiple memory slips or made mistakes that had never happened before. In both cases, the actual performance did not represent accurately the learning stage. There are many different factors that can affect these temporary shifts in performance; mood, stress, motivation, sleep loss, and anxiety, just to mention a few. Although learning can be inferred from certain performance changes, not all changes in performance can be interpreted as learning effects. Some (or many) may just be transitory.[7]

In this sense, it is important to understand how motor learning scientists measure learning and evaluate progress. Research in this field is usually done assessing two main parts of the learning process: the practice phase (acquisition) and the performance phase (retention). During the acquisition phase of the experiment, the researchers select the practice principles and variables that will be tested and divide the participants according to the needs of the study.[8] The most important part of the learning evaluation, however, is the next phase. After a period with no practice, subjects undertake tests called retention and/or transfer tests and perform the task that was practiced before. The interval between phases can last some minutes (immediate retention test) or can vary between hours, days,

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[7] Richard A. Schmidt and Timothy D. Lee, *Motor Learning and Performance: From Principles to Application*, 6th ed. (Champaign, IL: Human Kinetics, 2020), 181.
[8] Cheryl A. Coker, *Motor Learning and Control for Practitioners*, 4th ed. (New York: Routledge, 2018), 167, https://doi.org/10.4324/9781315185613.

weeks, and even longer periods of time (delayed retention test).[9] It is during this interval when forgetting may occur. Researchers then examine the scores from both phases to evaluate how much of the information was retained, comparing the results between groups to analyze which practice condition produced more effective outcomes. Transfer tests are assessed in a similar manner, but the test is on a novel task that shares a certain degree of similarity with the practiced task to evaluate how much of the previously acquired knowledge is transferred to the novel task.

This type of design is very useful because it mimics most skill learning situations, including music. Violin students, for example, spend hours in the practice room (acquisition phase) with the aim to perform what was practiced in front of the teacher, an audience, or simply to reproduce it well the next day (retention/transfer test). The difference between performance and learning is critical for musicians and pedagogues because it can lead to a better understanding of how to evaluate properly a certain practice technique or teaching method. As discussed in the next chapters, the motor learning literature presents many studies and experiments in which a practice tool had inferior scores during acquisition, but was far superior during retention/transfer tests. Thus, a good performance at the end of a violin practice session does not represent accurate gains on learning as well as a poor performance in a given violin lesson does not necessarily indicate a lack of practice or commitment from the student. The former might give an illusion on actual gains on learning and the latter might be due to a poor practice tool, a poor teaching method, or it might just be a temporary fluctuation in the

[9] William H. Edwards, *Motor Learning and Control: From Theory to Practice* (Belmont, CA: Wadsworth Cengage Learning, 2010), 173.

performance level. Understanding this and how to better approach teaching and practice, may help prevent much of the frustration from both students and teachers.

The single most important aspect that leads to skill acquisition is practice. Besides being logical, it is also supported by research. "More practice produces more learning."[10] However, practice is more than just repetition. Efficient practice involves thinking and problem-solving, is goal-oriented, and effortful. This is the essence of deliberate practice. Two desired outcomes of practice are to make the individual capable of reproducing the action as best as possible in the future (retention) and being able to apply the acquired knowledge to novel situations (transfer).

Considering this, the intent of this research paper is to provoke critical thinking on some traditional practice methods in music. Given that the motor learning literature findings are based on solid scientific research, musicians should revisit and reevaluate the long-held practices that conflict with motor learning research and put the "new" guidelines and recommendations to practical tests. Reviewing a wide variety of practice techniques through a scientific lens will provide valuable insights on the daily musical activities of violinists, and musicians in general.

[10] Schmidt and Lee, *Motor Learning and Performance*, 197.

CHAPTER 2

FOCUS OF ATTENTION

When performing an action, the individual's attention can be drawn to numerous different aspects of the task. For example, the violinist may pay attention to the pressure of the left-hand fingers when touching the fingerboard, the elevation of the right elbow when playing on the G string, or the mechanics of the bow arm to produce a specific movement. The player may also choose to direct their attention to the resulting sound, phrasing, or a specific dynamic that one wants to produce. Thinking about the different aspects of execution while practicing or performing is something with which most violinists are familiar. But does the focus of attention have an impact on learning and performance? Do the benefits for learning and performance change depending on to what the player is paying attention? The motor learning literature presents extensive research on this topic with very intriguing results and conclusions.

One of the ways that the literature categorizes attention is through the distinction between two different types of attentional focus: the internal focus of attention (IF) and the external focus of attention (EF).[11] An internal focus of attention is directed to the movement itself, usually to the bodily movements. Volleyball players focus internally when they pay attention to how their hands and arms move while executing a serve, for example. In violin playing that can be exemplified when players direct their attention to the different angles and shapes of the second finger when playing either F natural or F sharp in first position on the D string; or when one feels how the arm and hand travel in a challenging shifting. An external focus of attention is directed to the effects and results of

[11] Schmidt et al., *Motor Control and Learning*, Chap. 4.

the movement or to the intended target of the action. Using the previous examples, external focus happens when the volleyball player turns the attention to the intended ball trajectory or to the intended area that the player is targeting. Likewise, the violin player directs the attention externally when paying attention to the intended sound that results from placing the second finger on either F natural or F sharp on the D string in first position; or when they turn the attention to the target note when executing a challenging shifting.

A long-held view during the 20th century was that the learner should focus on how to move the limbs and the body in order to perform a skill well, i.e., they should use the internal focus of attention (IF) for best results.[12] This was believed to enhance both learning and performance. Since the 1990s, however, research has consistently demonstrated that having an external focus of attention (EF) produces, in most cases, better results for most individuals regardless of age, skill level, type of skill, and ability or disability.[13] Unlike some other practice conditions such as variable practice and contextual interference, also addressed in this paper, it is interesting to note that the advantages of the external foci are seen in both performance and learning, i.e., acquisition and retention, respectively.[14] [15]

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[12] Edwards, *Motor Learning and Control*, 371.
[13] Schmidt et al., *Motor Control and Learning*, Chap. 4.
[14] Gabriele Wulf, "Attentional Focus and Motor Learning: A Review of 15 Years," *International Review of Sport and Exercise Psychology* 6, no. 1 (September 2013): 78, https://doi.org/10.1080/1750984X.2012.723728.
[15] For reviews see Keith R. Lohse, Gabriele Wulf, and Rebecca Lewthwaite, "Attentional Focus Affects Movement Efficiency," in *Skill Acquisition in Sport: Research, Theory and Practice* (London: Routledge, 2012), 40–58; Gabriele Wulf and Wolfgang Prinz, "Directing Attention to Movement Effects Enhances Learning: A Review," *Psychonomic Bulletin & Review* 8, no. 4 (December 2001): 648–60, https://doi.org/10.3758/BF03196201; Gabriele Wulf and Rebecca Lewthwaite, "Effortless Motor Learning?: An External Focus of Attention Enhances Movement Effectiveness and Efficiency," in

2.1 Focus of Attention in Research

Experiments addressing focus of attention usually involve actions where participants are instructed about what to think while performing the task. For example, in experiments in hitting the ball in golf, participants were asked to focus on the swing of the club (EF) versus focusing on their arms (IF)[16] or to focus on the intended ball trajectory (EF) versus focusing on their wrists (IF).[17] This simple switch in focus led the external focus group to significantly outperform the internal focus group on retention. Similar results were found when participants were asked to focus on the pressure exerted either on their feet (IF) or on the wheels of the platform (EF) of a ski simulator,[18] and when individuals performing a basketball free-throw were asked to focus on the basket or on the ball trajectory (EF) versus focusing on the form of the movement or on the wrist

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Effortless Attention (The MIT Press, 2010), 75–101, https://doi.org/10.7551/mitpress/9780262013840.003.0004; Gabriele Wulf and Rebecca Lewthwaite, "Optimizing Performance through Intrinsic Motivation and Attention for Learning: The OPTIMAL Theory of Motor Learning," *Psychonomic Bulletin & Review* 23, no. 5 (October 2016): 1382–1414, https://doi.org/10.3758/s13423-015-0999-9; Schmidt et al., *Motor Control and Learning*, Chap. 11; Wulf, "Attentional Focus and Motor Learning."

16 Gabriele Wulf, Barbara Lauterbach, and Tonya Toole, "The Learning Advantages of an External Focus of Attention in Golf," *Research Quarterly for Exercise and Sport* 70, no. 2 (1999): 120–26, https://doi.org/10.1080/02701367.1999.10608029; Gabriele Wulf and Jiang Su, "An External Focus of Attention Enhances Golf Shot Accuracy in Beginners and Experts," *Research Quarterly for Exercise and Sport* 78, no. 4 (September 2007): 384–89, https://doi.org/10.1080/02701367.2007.10599436.

17 James J. Bell and James Hardy, "Effects of Attentional Focus on Skilled Performance in Golf," *Journal of Applied Sport Psychology* 21, no. 2 (May 6, 2009): 163–77, https://doi.org/10.1080/10413200902795323.

18 Gabriele Wulf, Wolfgang Prinz, and Markus Hob, "Instructions for Motor Learning: Differential Effects of Internal Versus External Focus of Attention," *Journal of Motor Behavior* 30, no. 2 (June 1998): 169–79, https://doi.org/10.1080/00222899809601334 Experiment 1.

(IF).[19] Furthermore, there is also evidence that EF leads to movement efficiency, i.e., it uses less muscle effort and energy when executing the task movements.[20]

It is very interesting to note that a simple change of words in instruction can have a great impact on the outcome. When intermediate crawl swimmers were asked to "focus on pulling your hands back" (IF) versus "focus on pushing the water back" (EF) for the arm stroke, or "focus on pushing the instep down" (IF) versus "focus on pushing the water down" (EF) for the leg kick, they achieved faster swim times in the external focus condition.[21] Similarly, in a study with gymnastic skills, superior movement form and greater jump height were found when participants adopted the instructions: "While airborne, focus on the direction in which the *tape marker* is pointing after the half turn" (EF) comparing to when they were asked: "While airborne, focus on the direction in which *your hands* are pointing after the half turn" (IF).[22] Related examples are "focus on the club motion" (EF) compared to "focus on the arm motion" (IF) in golf tasks[23] and "focus on the markers" (EF) versus "focus on your feet" (IF) in a balance task.[24]

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[19] Saleh A. Al-Abood et al., "Effect of Verbal Instructions and Image Size on Visual Search Strategies in Basketball Free Throw Shooting," *Journal of Sports Sciences* 20, no. 3 (January 2002): 271–78, https://doi.org/10.1080/026404102317284817; Tiffany Zachry et al., "Increased Movement Accuracy and Reduced EMG Activity as the Result of Adopting an External Focus of Attention," *Brain Research Bulletin* 67, no. 4 (October 2005): 304–9, https://doi.org/10.1016/j.brainresbull.2005.06.035.

[20] Jason Vance et al., "EMG Activity as a Function of the Performer's Focus of Attention," *Journal of Motor Behavior* 36, no. 4 (November 2004): 450–59, https://doi.org/10.3200/JMBR.36.4.450-459; Keith R. Lohse, David E. Sherwood, and Alice F. Healy, "Neuromuscular Effects of Shifting the Focus of Attention in a Simple Force Production Task," *Journal of Motor Behavior* 43, no. 2 (February 28, 2011): 173–84, https://doi.org/10.1080/00222895.2011.555436; Zachry et al., "Increased Movement Accuracy and Reduced EMG Activity as the Result of Adopting an External Focus of Attention."

[21] Andrea M. Freudenheim et al., "An External Focus of Attention Results in Greater Swimming Speed," *International Journal of Sports Science & Coaching* 5, no. 4 (December 2010): 536, https://doi.org/10.1260/1747-9541.5.4.533.

[22] Reza Abdollahipour et al., "Performance of Gymnastics Skill Benefits from an External Focus of Attention," *Journal of Sports Sciences* 33, no. 17 (October 21, 2015): 1809, https://doi.org/10.1080/02640414.2015.1012102. [emphasis in original].

[23] Wulf and Su, "External Focus of Attention Enhances Golf Shot Accuracy," 387.

[24] Wulf, Prinz, and Hob, "Instructions for Motor Learning: Differential Effects of Internal Versus External Focus of Attention," 169.

These findings are very robust with support from several experiments both in laboratory and applied settings, as well as in a variety of types of tasks and skills for both beginners and experts.[25] Other examples are experiments with discus throwing,[26] soccer,[27] jumping,[28] dart throwing,[29] sprinting,[30] swimming,[31] piano,[32] voice,[33] and a various instruments,[34] to mention a few.

2.2 The Constrained Action Hypothesis and Automaticity

The most accepted theory explaining why external focus of attention is more beneficial for learning and performance than internal focus is the constrained action

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[25] Wulf, "Attentional Focus and Motor Learning," 95.
[26] Mehdi Zarghami, Esmaeel Saemi, and Islam Fathi, "External Focus of Attention Enhances Discus Throwing Performance," *Kinesiology* 44, no. 1 (June 2012): 47–51.
[27] Gabriele Wulf, Sebastian Wächter, and Stefan Wortmann, "Attentional Focus in Motor Skill Learning: Do Females Benefit from an External Focus?," *Women in Sport and Physical Activity Journal* 12 (April 1, 2003): 37–52, https://doi.org/10.1123/wspaj.12.1.37.
[28] Jared M. Porter et al., "Standing Long-Jump Performance Is Enhanced When Using an External Focus of Attention:," *Journal of Strength and Conditioning Research* 24, no. 7 (July 2010): 1746–50, https://doi.org/10.1519/JSC.0b013e3181df7fbf.
[29] Keith R. Lohse, David E. Sherwood, and Alice F. Healy, "How Changing the Focus of Attention Affects Performance, Kinematics, and Electromyography in Dart Throwing," *Human Movement Science* 29, no. 4 (August 2010): 542–55, https://doi.org/10.1016/j.humov.2010.05.001; David C. Marchant, Peter J. Clough, and Martin Crawshaw, "The Effects of Attentional Focusing Strategies on Novice Dart Throwing Performance and Their Task Experiences," *International Journal of Sport and Exercise Psychology* 5 (January 1, 2007): 291–303, https://doi.org/10.1080/1612197X.2007.9671837.
[30] Jared M. Porter et al., "Adopting an External Focus of Attention Improves Sprinting Performance in Low-Skilled Sprinters," *Journal of Strength and Conditioning Research* 29, no. 4 (April 2015): 947–53, https://doi.org/10.1097/JSC.0000000000000229.
[31] Isabelle Stoate and Gabriele Wulf, "Does the Attentional Focus Adopted by Swimmers Affect Their Performance?," *International Journal of Sports Science & Coaching* 6, no. 1 (March 2011): 99–108, https://doi.org/10.1260/1747-9541.6.1.99.
[32] Robert A. Duke, Carla D. Cash, and Sarah E. Allen, "Focus of Attention Affects Performance of Motor Skills in Music," *Journal of Research in Music Education* 59, no. 1 (April 2011): 44–55, https://doi.org/10.1177/0022429410396093.
[33] Rebecca L. Atkins, "Effects of Focus of Attention on Tone Production in Trained Singers," *Journal of Research in Music Education* 64, no. 4 (January 2017): 421–34, https://doi.org/10.1177/0022429416673842; Rebecca L. Atkins, "Focus of Attention in Singing: Expert Listeners' Descriptions of Change in Trained Singers' Tone Quality," *International Journal of Research in Choral Singing* 6 (2018): 3–24.
[34] Adina Mornell and Gabriele Wulf, "Adopting an External Focus of Attention Enhances Musical Performance," *Journal of Research in Music Education* 66, no. 4 (January 2019): 375–91, https://doi.org/10.1177/0022429418801573.

hypothesis offered by Wulf and her colleagues.[35] According to this hypothesis, an internal focus of attention leads to a more conscious type of control, which tends to constrain the motor system, thus disrupting the free flow of an automated type of movement. On the other hand, focusing on the movement effects, i.e., external focus of attention, promotes "a more automatic mode of control by utilizing unconscious, fast, and reflexive control processes."[36] Thus, when the attention is directed externally, the individual naturally uses automated motor control processes to produce the action, which may even facilitate learning. According to Schmidt et al., "external focus of attention facilitates learning so that motor skills are controlled automatically, and performed with greater effectiveness and efficiency, sooner."[37] Moreover, in Gabriele Wulf's literature review, she discusses several studies that demonstrate the external focus of attention promoting automaticity.[38]

2.2.1 Choking and focus of attention

Skilled performance is typically characterized by high levels of automaticity, movement effectiveness, and efficiency.[39] Sometimes, even skilled performers may experience declines in performance levels accompanied by unexpected fails, especially under pressure situations. This phenomenon is called choking[40] - an undesirable outcome

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[35] Gabriele Wulf, Nancy McNevin, and Charles H. Shea, "The Automaticity of Complex Motor Skill Learning as a Function of Attentional Focus," *The Quarterly Journal of Experimental Psychology Section A* 54, no. 4 (November 2001): 1143–54, https://doi.org/10.1080/713756012; Wulf and Lewthwaite, "Effortless Motor Learning?"

[36] Wulf, "Attentional Focus and Motor Learning," 91.

[37] Schmidt et al., *Motor Control and Learning*, Chap. 4.

[38] Wulf, "Attentional Focus and Motor Learning," 91.

[39] E. R. Guthrie, *The Psychology of Learning*, (New York: Harper & Row, 1952), quoted in Schmidt et al., *Motor Control and Learning*, Chap. 4.

[40] Sian L. Beilock and Thomas H. Carr, "On the Fragility of Skilled Performance: What Governs Choking Under Pressure?," *Journal of Experimental Psychology. General* 130, no. 4 (2001): 701, https://doi.org/10.1037/0096-3445.130.4.701.

for any performer. According to Beilock,[41] choking happens more often when there is a shift in one's focus of attention. In line with the constrained action hypothesis, when expert performers shift to an internal focus of attention, they might experience disruption in the execution of the task, negatively affecting performance. Thus, if the skilled performer starts to think on the movements themselves and tries to overcontrol them instead of keeping the free flow of the already well-learned automated and reflexive movements, the likelihood of choking increases significantly. As a result, anxiety may occur causing the performer to over-control their movements, and the performance can deteriorate if this pattern is not broken. Anxiety can often be the impulse for the shift of attentional focus, a phenomenon that surely resonates with many violinists.

In the nineteenth century, the theorist J.M. Cattell was already speculating about attention and automaticity in expert performers. "In piano playing, the beginner may attend to his fingers but the practiced player attends only to the notes or to the melody. In speaking, writing and reading aloud, and in games and manual work, attention is always directed to the goal, never to the movement. In fact, as soon as attention is directed to the movement, this becomes less automatic and less dependable."[42] Moreover, results from experiments indicate that using internal focus of attention may be not only less effective than external focus, but it also may hinder performance and learning (e.g., a study in a

[41] Sian Beilock, *Choke: What the Secrets of the Brain Reveal about Getting It Right When You Have To* (Riverside: Atria Books, 2010), 86.
[42] Cattell, J. M, *Attention and reaction*, trans. R.S. Woodworth, "James McKeen Cattell, Man of Science," *Psychological Research* 1 (1947): 252-255. Originally publishes as "Aufmerksamkeit und reaction," *Philosophische Studien* 8 (1893): 403-406, quoted in Schmidt and Lee, *Motor Learning and Performance*, 65.

dart-throwing task[43] and in swimming skills[44]). In such experiments, subjects in the IF condition demonstrated poorer results than subjects not only in the EF condition, but also those in the control group who were not asked to have any specific focus. On the other hand, there is evidence that exerting external foci when practicing may help to maintain levels in future performances, even under pressure[45] and/or anxiety conditions.[46]

2.3 Distance Effect

Although the positive effects of external focus of attention on learning and performance have great support from research, there are many different parts of the task to which learners can pay attention. For example, when about to hit the ball, a tennis player may choose to focus on the racket, the ball, the intended trajectory of the ball, or on hitting a specific target area. All would be considered external focus of attention, but they represent different aspects of the action and are at different "distances" from the player's body. There is evidence that not all focal distances are equally effective; focusing on greater distances from the individual's body seems to lead to better results, as long as the focus is still task related. This is called distance effect.[47]

One of the first experiments showing the distance effect was conducted by McNevin, Shea, and Wulf in 2003.[48] In a balance task using a stabilometer, they tested

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[43] David E. Sherwood, Keith R. Lohse, and Alice F. Healy, "Judging Joint Angles and Movement Outcome: Shifting the Focus of Attention in Dart-Throwing," *Journal of Experimental Psychology: Human Perception and Performance* 40, no. 5 (October 2014): 1903–14, https://doi.org/10.1037/a0037187.
[44] Stoate and Wulf, "Does the Attentional Focus Adopted by Swimmers Affect Their Performance?"
[45] Nicole T. Ong, Alison Bowcock, and Nicola J. Hodges, "Manipulations to the Timing and Type of Instructions to Examine Motor Skill Performance Under Pressure," *Frontiers in Psychology* 1 (2010): 1–13, https://doi.org/10.3389/fpsyg.2010.00196.
[46] Bell and Hardy, "Effects of Attentional Focus on Skilled Performance in Golf."
[47] Edwards, *Motor Learning and Control*, 376.
[48] Nancy H. McNevin, Charles H. Shea, and Gabriele Wulf, "Increasing the Distance of an External Focus of Attention Enhances Learning," *Psychological Research* 67, no. 1 (February 2003): 22–29, https://doi.org/10.1007/s00426-002-0093-6.

different external focal points. Along with the traditional external versus internal groups, they added three external focus groups. The external far outside group (EFO) was instructed to focus on the marks close to the edges of the platform, the external far inside group (EFI) was instructed to focus on the marks right between their feet, the external near group (EN) was instructed to focus on the marks right in front of their feet, and the internal focus group (IF) was instructed to focus on their feet. All individuals were asked to look straight ahead to the wall in front of them while performing the task, not to the marks. In this way, the results would not be influenced by the visual focus. Results showed that the EF groups outperformed the IF groups and the two far external groups (EFO and EFI) got even better results than the EN group, supporting the distance effect theory. In similar studies, distal focal points got better results in racing times when experienced kayakers focused on the finish line instead on the paddles,[49] subjects with no soccer experience got better scores and less technical errors when they focused on the target as opposed to the ball,[50] dart-throwing task participants were more accurate when they focused on the bull´s-eye instead on the intended trajectory of the dart,[51] and experienced golfers reduced their number of strokes when they focused on the trajectory of the ball and landing points as opposed to focus on the club, even when in a high-pressure situation.[52]

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[49] Stephen Banks et al., "Forward Thinking: When a Distal External Focus Makes You Faster," *Human Movement Science* 74 (December 2020): 102708, https://doi.org/10.1016/j.humov.2020.102708.
[50] Aiman Sarhan, "Attentional Focus Effect on Learning Dribbling and Passing in Soccer" (PhD, Detroit, MI, Wayne State University, 2018).
[51] Brad McKay and Gabriele Wulf, "A Distal External Focus Enhances Novice Dart Throwing Performance," *International Journal of Sport and Exercise Psychology* 10, no. 2 (June 2012): 149–56, https://doi.org/10.1080/1612197X.2012.682356.
[52] Bell and Hardy, "Effects of Attentional Focus on Skilled Performance in Golf."

Furthermore, the experiment by Duke, Cash, and Allen testing a brief piano sequence with music majors (pianists and non-pianists) supports the distance effect in musical settings as well.[53] Participants were asked to focus either on their fingers (IF), on keyboard keys (proximal EF), piano hammers (distal EF), or in the resulting sound (far distal EF). Results showed greater accuracy when they were exposed to more distal focal points (i.e., resulting sound). It is important to stress that researchers usually ask all participants to maintain the same visual focus independently of their condition or group, so that the attentional focus is not influenced by vision. Experiments aim to address what participants are thinking when performing, not what they are seeing.

2.3.1 Optimal external focus distance

One might be tempted to conclude that everyone should then focus always on the farthest focal point. However, far distal focus may not be appropriate on every occasion and for every skill level. Some researchers argue that optimal external focus distances depend on the skill level of the learner. Wulf and Su state that "it seems reasonable to assume that the optimal focus varies with the skill level."[54] According to them, more experienced learners tend to experience better success from more distal focus, while novices tend to need a more proximal focus of attention. Thus, as skill level improves, optimal focus is said to become more distal. This argument has support from research that compared different external focal distances in golf pitch shots using subjects of different levels of expertise. While novices showed better results when they focused on

[53] See Duke, Cash, and Allen, "Focus of Attention Affects Performance of Motor Skills in Music."
[54] Wulf and Su, "External Focus of Attention Enhances Golf Shot Accuracy," 388.

the club,[55] experts showed better outcomes when they focused on the ball trajectory or target area.[56]

Although further research is needed to address the optimal distal focus in different types of skills (e.g. open, closed, discrete, continuous, and serial) and across different age groups, skill levels, and task difficulty, "it makes sense that relatively inexperienced performers, who are still in the process of acquiring the basic movement pattern, would benefit more from an external focus that is technique related (or more proximal)."[57] A beginner violin student, for example, will probably not take any advantage when thinking on the desired sound if s/he has not learned how to properly hold the bow yet. On the other hand, asking a concert violinist to pay attention to the bow hold while playing, may disrupt the performance. It seems reasonable therefore to suggest that instructions and actions have better outcomes when controlled at the most distal focus possible for each individual in his/her respective learning stage.[58]

2.4 Research in Music

In the past decade, there has been a growing interest in experiments testing different foci of attention in musical settings. Studies testing simple tasks, complex excerpts, different focal distances, and a variety of instruments, already give a general idea that focus of attention is an effective tool in music teaching and learning environments.

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[55] Gabriele Wulf et al., "Attentional Focus in Complex Skill Learning," *Research Quarterly for Exercise and Sport* 71, no. 3 (September 2000): 229–39, https://doi.org/10.1080/02701367.2000.10608903 Experiment 2.
[56] Bell and Hardy, "Effects of Attentional Focus on Skilled Performance in Golf."
[57] Schmidt et al., *Motor Control and Learning*, Chap. 10.
[58] Wulf and Su, "External Focus of Attention Enhances Golf Shot Accuracy," 388.

The first study is the already mentioned experiment conducted by Duke, Cash, and Allen. They selected sixteen music majors (four advanced pianists and twelve orchestral musicians) and used a within subject design (all participants performing in all conditions).[59] The task was to play a sequence of sixteenth notes alternating pitches F and A in a fast tempo. Subjects were asked to focus either on their fingers (IF), on keyboard keys (proximal EF), piano hammers (distal EF), or in the resulting sound (far distal EF). Far distal focus produced better results in both acquisition and transfer phases for the orchestral musicians. Piano majors, however, seemed not to be affected by any condition in any phase. The fact that the task was very simple probably explains the reason why pianists performed the task well independently of their focus. An uncomplicated two-finger pattern probably had a very low difficulty level for expert pianists and therefore produced a ceiling effect.[60]

Atkins and Duke conducted an experiment measuring performance only, with thirty untrained singers singing a three-note pattern using one vowel [α] under 5 different conditions (all participants performed in all five conditions).[61] The conditions were: a) direct the attention to the vibration of the throat while feeling it with the palm of one hand; b) focus on directing the sound to the fingertips of the index and middle fingers that were placed either on side of the nose (called mask condition); c) direct the sound to the microphone that was 18 inches far from the participant; d) direct the sound to the wall in

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[59] See Duke, Cash, and Allen, "Focus of Attention Affects Performance of Motor Skills in Music."

[60] Ceiling effect is when the measured levels of a variable, approach the highest values, independently of the condition, making a meaningful analysis impractical.

[61] See Rebecca L. Atkins and Robert A. Duke, "Changes in Tone Production as a Function of Focus of Attention in Untrained Singers," *International Journal of Research in Choral Singing* 4, no. 2 (2013): 28–36.

a point across the room; e) a control condition where no specific instructions were given. The authors considered the throat condition as proximal internal, the mask condition as distal internal, the microphone as proximal external, and the wall as distal external. Recordings were evaluated by expert listeners who ranked each of them in relation to the tone quality in a scale from 1 (best) through 5 (worst) for each participant. Results showed the lowest ranks (4-5) for the control and throat condition, while the mask, microphone, and wall received the best ranks (1-2).

One would expect the wall condition to receive the best ranks for everyone because of the distance effect. However, most singers received a score of 1 when singing in either the mask or microphone conditions. Nevertheless, that does not contradict the distance effect. On the contrary, it corroborates with the findings of optimal focal distances. The subjects in this experiment were untrained singers and probably the wall was not in the optimal distance focus for their level. It is also noteworthy that no participant received a rank of 5 in the wall condition which indicates that the wall condition was already better than the internal condition. In this way, these findings encourage teachers to always test different attentional focal distances with their students in order to find the optimal distance for each case.

More straightforward results were found in two studies with expert singers conducted by Rebecca Atkins.[62] In both experiments, singers performed a musical excerpt and a vocalise under six different focal distances. The different conditions included focusing on the soft palate positioning, focusing on keeping their vibrato steady,

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[62] See Atkins, "Effects of Focus of Attention on Tone Production in Trained Singers"; Atkins, "Focus of Attention in Singing: Expert Listeners' Descriptions of Change in Trained Singers' Tone Quality."

focus on directing the sound toward a circle that was nineteen feet across the room, and imagining "filling the room" with sound. In both experiments, singers got the best ratings in the most distal focus conditions. Thus, as expected, expert singers benefited the most from far focal distances. It is important to emphasize that the tasks included musical excerpts, which gave a further realistic musical setting to the study.

Along those lines, a very recent and quite interesting research study by Mornell and Wulf also found superior results for the external focus condition in two experiments.[63] Skilled musicians (graduate and undergraduate music major students in their respective instruments) were asked to perform a piece of their choice. In the EF condition, they were told to focus on playing for the audience as well as to focus on the expressive sound of the music. In the IF condition they were asked to focus on the precision of their finger movements (or lip movements in the case of singers) and to the correct notes. In the control condition they were not given a specific focus to think about.

In both experiments EF led to better results. In Experiment 1, results showed that EF led to superior musical expression, as evaluated by expert raters, but there was no statistical difference on technical precision between conditions, although "highest numerical scores for technical precision were seen in the external focus condition as well."[64] In Experiment 2, results revealed that the EF condition led to both superior musical expression and technical precision. The difference between experiments was mostly in the scoring system where Experiment 2 had more specific and detailed evaluation criteria. Specifically, in the first experiment evaluators were asked to give

[63] See Mornell and Wulf, "Adopting an External Focus of Attention Enhances Musical Performance."
[64] Mornell and Wulf, 381.

scores on either the overall technical precision and overall musical expression, while in the second experiment they were asked to evaluate separately specific items for musicality (expression, tempo variations, interpretation, and stage presence) and technical precision (notes, rhythm, phrasing, dynamics, and fluency of movement). It is very interesting that focusing on the precision of the movement did not lead to better technical precision in either experiment.

Two prominent strengths of this study are the representation of a variety of instruments (violin, piano, guitar, voice, clarinet, cello, percussion, tuba, accordion, saxophone, and horn), and the use of complex musical tasks (a three-minute-long piece of music) instead of just technical exercises. Moreover, the experimenters also sought to create a somewhat pressure environment testing the participants in a concert hall with recording equipment and chairs arranged in a semi-circle. Thus, these results also suggest that external foci may be beneficial to pressure situations as well.

Two studies by Laura Stambaugh resulted in inconclusive findings. In the first study, with the aim to reproduce a similar design of Duke, Cash, and Allen's study, Stambaugh selected fifteen novices and fifteen experienced woodwind players to perform on their instruments a similar task as the piano experiment.[65] All subjects were music majors; while the novices were not woodwind majors, the experienced players' primary instruments were clarinet, oboe, or saxophone. All were exposed to control, internal (fingers), near-external (keys), and far-external (sound) conditions in a two-day protocol. All participants played first under the control condition and were then assigned to the

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[65] Laura A. Stambaugh, "Effects of Internal and External Focus of Attention on Woodwind Performance.," *Psychomusicology: Music, Mind, and Brain* 27, no. 1 (2017): 45–53, https://doi.org/10.1037/pmu0000170.

remaining conditions. The two dependent variables measured were note accuracy and sound evenness. The study could not achieve a consistent generalizable finding. The only general trend was that both novices and experts tended to be slightly less accurate as the distal focus increased. These findings contradict the general findings of most focus of attention experiments, but, as reported by Stambaugh herself, the differences were not significant. Furthermore, the task was very simple, purely mechanical and, one can argue, lacked musical meaning. This was not the case with the studies by Mornell and Wulf, as well as by Atkins.

In the second study by Stambaugh, she selected seventh grade middle school band students as subjects.[66] The analysis included twenty-five woodwind players, sixteen valved brass players, and ten trombonists. The experiment measured sound evenness in a two-day protocol under three conditions: control, IF (fingers), and EF (sound). The study reported that there were no significant differences between the three conditions in either acquisition or retention phases. It is noteworthy that even the control condition was no different from the two focus of attention groups. At the individual level, the study showed mixed findings, with some students playing more evenly under IF, others under EF, and others under control conditions. There are several potential weaknesses in this study, however. First, it failed to show differences between the control and attentional focus conditions. The study did not report if there was a significant difference in performance between the beginning of the acquisition phase and the retention test, thus, it is not possible to know whether learning really occurred (at least with the data reported).

[66] Laura A. Stambaugh, "Effects of Focus of Attention on Performance by Second-Year Band Students," *Journal of Research in Music Education* 67, no. 2 (July 2019): 233–46, https://doi.org/10.1177/0022429419835841.

Finally, the study also reported that there were no measures to check if the students were really adhering to the instructions about what to focus on.[67] Thus, it is premature to draw conclusions based on these two experiments, especially in face of a vast amount of research supporting the benefits of external foci, including music.

The motor learning literature shows overwhelming evidence of the benefits of EF both in practice and performance. Although musicians are often encouraged to think internally to their fingers, limbs, and to their bodies in general while performing, they may be positively surprised by the benefits of directing their attention externally. The next chapter shows how to apply principles of focus of attention to violin teaching and learning, including discussions about the distance effect.

[67] Stambaugh, 243.

CHAPTER 3

FOCUS OF ATTENTION APPLIED TO VIOLIN PEDAGOGY

In order to apply principles of internal and external focus of attention to violin pedagogy, it is important to first establish what can be considered external and internal focus in violin playing as well as the different levels of external focus when considering the distance effect. Thus, the present chapter intends to present a classification system for internal and external focus of attention in violin pedagogy and suggestions on how to apply these concepts.

The definition from the motor learning literature, as discussed earlier, states that internal focus happens when the attention is directed towards the bodily mechanics and/or to the movements themselves, while external focus happens when the attention is directed to the effects of the actions and/or to what is external to the body.[68] External focus of attention is believed to be more beneficial for learning and performance and more reliable under pressure situations[69] than internal focus of attention.

The concept of cause and effect gives further insight. If we consider that the bodily movements are what cause the actions and internal focus is the attention directed to the bodily mechanics, then internal focus can also be viewed as the focus directed to the causes. From this perspective, external focus happens when the attention is directed to the expected outcome while internal focus happens when the attention is directed to what needs to be done for that outcome to happen. In fact, in violin playing, the body is what causes the instrument to move in a certain way which then generates sound. For

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[68] Schmidt et al., *Motor Control and Learning*, Chap. 4.
[69] See Bell and Hardy, "Effects of Attentional Focus on Skilled Performance in Golf."

example, when playing *detaché,* the right hand, arm, wrist, and fingers move in a certain way that causes the bow to move in a specific manner, speed, place, force, and weight producing the sound of the *detaché*. We can also add that the sound, or combination of different sounds, may ultimately produce an emotional impact on the listener. From this perspective, it is possible to divide attentional focus into four categories as seen in Figure 1 and discussed in more detail in the next section.

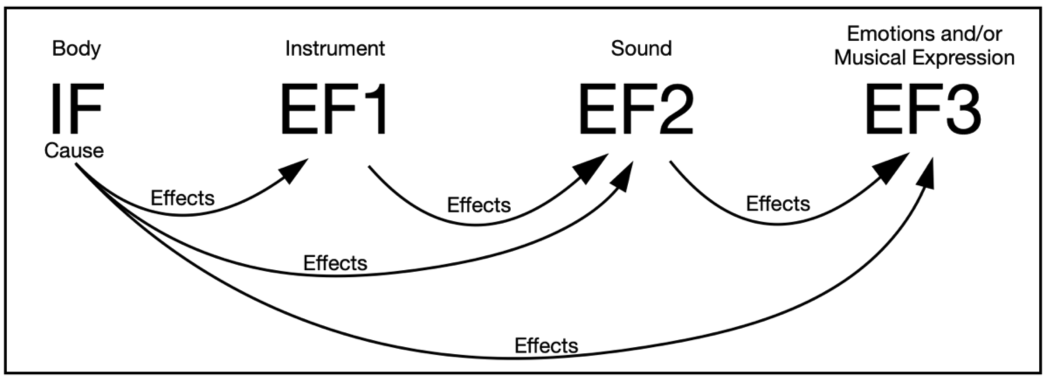

Figure 1. Attentional focal distances and their cause/effect relationship (All figures created by author unless otherwise noted)

Although external focus is more beneficial in most cases, sometimes the player or the teacher may need to direct the focus to the cause because understanding how to move to produce the action is necessary and can be even more efficient on occasion. However, this should be temporary; once the individual understands what the effect is, how to cause it, and the principles behind it, it may be counterproductive to keep the focus on the cause. In fact, according to the constrained action hypothesis, moving the focus to the effects will promote more automaticity of the mechanisms that cause it, while keeping or moving the focus to the cause may disrupt the performance.[70]

[70] Wulf, "Attentional Focus and Motor Learning," 91.

3.1 Distance Effect and Violin Pedagogy

When performing a motor skill, the body movements produce multiple effects for each task. When playing the violin, the body initiates different movements of the bow (including different speeds and angles), friction between the bow hair and the strings, alteration of the length of the string by pressing down with the left-hand fingers, vibration of the strings, etc. The combination of those movements generates a variety of sounds, dynamics, pitches, rhythms, timbres, and articulations, which then may generate different musical expressions and emotional effects. Thus, violinists are left with many options of EF to direct their attention.

Directing the attention to different aspects of the action may represent different focal distances. Not all external foci are equally effective to all individuals in all circumstances. According to the distance effect theory, more distal foci are more effective in general, especially for more advanced learners. However, there is an optimal distance for each individual and learning stage, which depends on the individual, their level, the passage, and the difficulty of the task.[71] It can even have different outcomes for the same individual with the same passage, but in different learning stages, even within the same week.

[71] Chap. 10 Schmidt et al., *Motor Control and Learning*.

Table 1. Description of internal and external focus of attention on violin pedagogy

	a) Internal Focus	b) External Focus 1	c) External Focus 2	d) External Focus 3
	Bodily Mechanics	Instrument Related Aspects	Sound Image Desired/Resulting Sound	Emotional Intentions Musical Expression
1) Description	The focus directed to body parts, on how they move and behave, and/or on muscle force.	The focus directed to instrument parts, on how they move and behave, and the relationship between them. It may include analogies to portrait the tasks.	The focus directed to the desired, expected, and/or resulting sound. It involves imagining every detail of the sound/passage as precise as possible. It may include analogies to portrait the desired sound.	The focus directed to the musical expression and/or on the emotional intentions. It may include analogies to portrait the intentions.
2) Examples to what to direct the attention	Hands, fingers, wrists, arms, forearms, elbows, neck, shoulders, back, head, chin, joints, etc.	Bow Movements, direction, trajectory, hair behaviors, speed, upper half, middle, lower half, vertical and horizontal angles, bounce, pressure/weight against the strings. Violin Location of the notes on the fingerboard Point of contact Distance between bridge or fingerboard and the bow Vibration of the strings Imagining sound coming out of the f holes Height of the scroll Angle of the violin Releasing excessive pressure against the neck of the violin Releasing excessive pressure against the chinrest and shoulder rest	Articulations, bow strokes, types of vibrato, correct pitch, dynamics, timbre, rhythm, types of portamentos or slides, types of shifting, attacks, releases, phrasing, direction, rubato, nuances, style.	Moods, emotions, abstract analogies, sound colors, taste. Happy, angry, calm, agitated, cheerful, reflective, humorous, melancholic, mysterious, lighthearted, hopeful, lonely. Joy, excitement, surprise, sadness, love, passion, light, dark, hot, cold, soft, harsh, whisper, powerful, weak, full, bitter, sweet.
3) Observations	There are several situations that IF is almost unavoidable. Analogies may help greatly to push the focus to EF1 in some of those situations. **Examples:** **Vibrato** - knock the door; **Shifting** - release the string quickly as if the fingerboard was really hot; **Tension on left hand** - pretend that the fingerboard is made out of water and don't let the fingers sink in it; or hand feeling like a marshmallow. **Posture** - Visualize a string pulling your head upwards;	There are several effects that happen on the instrument when it is manipulated. Our body causes the strings to vibrate, the different lengths of the strings when pressed down, the bow hair to bend, and the movements on the bow with its different speeds, angles, and affected regions. A single task may involve multiple parts in which the player may direct the focus. The attention may be shifted to a different aspect in different trials. It is important, however, to choose a part that is involved in the task, or that is part of the current goal.	Sound image is the exact mental blueprint of the desired sound. 'Listening' to a sound or sequence of sounds in the mind is recovering the 'image' of the sound that is stored in the memory. The focus can be narrow or broad, i.e., the sound can be imagined isolated or in segments, phrases, sections, movements, and pieces. Comparing the expected with the actual results may automatically lead to adjustments and to the search for solutions to achieve the desired sound.	In general, this level of external focus of attention is recommended to more advanced players. Nevertheless, one may draw benefits with beginners in some occasions as well. Directing the focus to the musical expression may directly influence the other levels, i.e., it may change how one imagines the phrase and, consequently, how the instrument should be manipulated.

As the individual gets more skilled, they tend to draw more benefits from farther distances. Thus, students should be encouraged to explore and experiment with different focal points while practicing. External focus of attention can be divided into three general levels that represent three different focal distances in violin pedagogy: instrument-related aspects (EF1), desired sound or the sound image (EF2), and emotional intentions or musical expression (EF3) (see Table 1). Violin students and players, as well as teachers, can apply these concepts. Violinists may use external focus during practice and performance, while teachers may use language that leads to external focus of attention when instructing their students.

Choosing and applying external focus of attention to the daily routine may be challenging sometimes. One must use good sense, constantly testing which level of EF is better suited for each person and occasion. The goal is certainly to use higher levels of EF whenever possible, but in practical terms, it is most likely that multiple "distances" of focus of attention will be used, even in the same session.

3.2 External Focus 1: Instrument Related Aspects

Directing the focus to instrument-related aspects is the "closest" external focus level. One of the propositions of the focus of attention concept is to avoid instruction and attentional focus that leads primarily to the body or to the self. In this sense, focus or instruction that leads to the parts of the instrument is more desirable than to the individual's own body (see Table 1 column B). For example, directing the attention to the bow and the bridge may be more effective than focusing on the arm and its mechanics when aiming to keep the bow parallel to the bridge. When dealing with problems of tension on the left hand, instead of saying "be careful with the tension you are exerting on your left hand," it may be more effective for the teacher to say, "be careful with the tension you are exerting towards the neck of the violin." This simple change of words can make a great difference as shown in numerous studies previously discussed. Additionally, in order to help reducing body-focused instructions, Wulf suggests the use of metaphors and analogy,[72] which endorses the approach of many music teachers who have already been using analogies due to their imaginative appeal (see Table 1 column A, line 3).

When using EF1, it is important for the player to direct the focus to something related to the task. Merely focusing on a part of the instrument is not what will enhance performance and learning. The player must ask him/herself what the effects of the action are, what are its results, and what is involved to produce that task. It may not be effective to focus on the chinrest if the goal is to produce an even sound, for example. In this case, it may be more productive to direct the focus to some aspect of the bow or to some related violin part (e.g., the stick, the bow hair, the pressure/weight of the bow against the string, the bow speed, the bow trajectory, the point of contact, the vibration of the strings, etc.). One might draw benefits from directing the attention to the chinrest if the goal is to release tension from the neck and shoulder. For example, focusing on releasing the pressure against the chinrest (EF) instead of focusing on the neck muscles themselves (IF).

It is important to acknowledge, however, that in violin pedagogy sometimes it is very hard, or even impractical not to give instructions that lead to bodily parts and avoid completely internal focus of attention. Sometimes the teacher may need to use IF language. Clear examples are when teaching or correcting posture, bow hold, shape of the

[72] Gabriele Wulf, *Attention and Motor Skill Learning* (Champaign, IL: Human Kinetics, 2007), 61.

hand, etc. The teacher may explain how the hands and fingers are properly positioned on the violin and bow and direct the student's focus to the body in order to keep proper position, especially in the beginning.

Nevertheless, the teacher may find creative ways to use EF language even for those harder cases; teachers who introduce children to the violin often use analogies (which is a type of external focus language) that help the learning process. For example, "pretend that the neck of the violin is lava and if the palm of your left hand touches it, you might get burned" as opposed to "keep your left wrist straight" or "don´t touch the violin with the palm of your left hand"; and "pretend that your violin is a table full of food. If it is tilting downwards the food will fall on the floor, if it is tilting upwards then it will fall on you" as opposed to "lift your left hand to keep your violin higher". Nevertheless, good sense is critical as there will be occasions that do require the teacher to use IF language as the most effective way of instruction.

In general however, the tradition of using IF language in violin pedagogy is not as effective as when EF is employed. For example, playing with the bow parallel to the bridge is an important element of violin playing. It is not unusual to find teachers who want to explain exactly how the right arm should behave and all its mechanics and then ask the students to focus on it to keep the bow straight. This is a much more complex process for both the student and the teacher as opposed to asking the student simply to focus on the bow itself and its trajectory, or on the point of contact, or on the distance between the bridge and the bow hair, or even playing in front of a mirror. In most cases, the bow traveling straight will automatically make the mechanics of the right arm behave correctly, which corroborates with the constrained action hypothesis that says that EF activates automatic processes that produce the movement.

3.3 External Focus 2: Desired Sound and Sound Image

Although substituting IF for EF1 language may already produce great improvements in learning, pushing the EF to a "farther distance" may be even more desirable, especially in more advanced learning stages. The next level (EF2) is the focus directed to the resulting sound, or what I have termed as the sound image, which is the exact mental blueprint of the expected sound. The end-product of playing an instrument is in fact to produce sound. Holding the instrument in a certain way or placing the bow on the string in a specific place and manner are not the final product, but they are means to achieve the final goal, which is sound, music, and sound effects (see Table 1, column C).

There is a reason beyond simple aesthetics why violinists aim for keeping the bow parallel to the bridge. By doing so, the bow maintains a more consistent point of contact, resulting in a cleaner, uniform, and focused sound. Not playing with a "straight" bow may result in numerous sound issues. When using EF1 the player may choose to focus, for instance, on the point of contact, on the bridge, or on the bow trajectory, as previously mentioned. In the EF2, however, the intention is for the player to focus on the resulting sound instead of focusing on the bow or on the instrument. From the external focus of attention perspective, when aiming to produce the desired sound, the violinist will automatically seek to adjust the bow in order to find solutions to achieve what is intended. Besides the potential learning benefits that the external focus of attention brings, it stimulates the development of problem-solving skills and aural skills as well.

Notice that the bow parallel to the bridge is just one element that can affect sound production in violin playing. There are also other elements, such as bow speed, point of contact, and the pressure (or weight) that the bow exerts on the string. All these variables are interrelated and influence each other. There are numerous (if not infinite) possible combinations of these parameters. The process of trying to consciously control all those variables is much more complex than focusing on the desired sound while adjusting the various parameters automatically.

Focusing on achieving a specific sound image is not a foreign concept to violin pedagogy. In his book The Violin Lesson, Simon Fischer states that practicing tone production, for example, should "follow the principle of always beginning with the result you want, and working your way back from there, rather than 'starting from nowhere'. Always go straight for the tone and the expression, *and then find how to do it*, rather than the other way around."[73] Thus, students could be trained to imagine and to listen to the resulting sound, and whenever it is not sounding as desired, they will look for proper solutions and, from the external focus perspective, much of these adjustments will happen automatically and even unconsciously.

One may argue that using EF2 may not work for beginners because they do not have the technical expertise and automaticity to make automatic adjustments nor is their sound perception or musicality well developed yet. This observation certainly needs to be taken into consideration. However, training students, even beginners, to primarily aim to the desired sound while making technical adjustments to achieve it, may be proven to be

[73] Simon Fischer, *The Violin Lesson: A Manual for Teaching and Self-Teaching the Violin* (London: Peters, 2013), 1 [emphasis added].

more effective than training them only to achieve good technique per se. In fact, in my experience as a violin teacher, I have anecdotal evidence that students in the very early stages of learning can already make automatic adjustments when thinking about the sound. One example was a nine-year-old student of mine who had been playing the violin for about four months. Her sound was very week and lacked focus. The obvious technical problem was that she was playing with her bow too close to the fingerboard. It did not matter what I asked her, whether asking to play closer to the bridge, away from the fingerboard, having her play in front of the mirror, physically guiding her bow, etc.; she was unable to fix the technical problem and, consequently, the sound. Then I decided to play for her, and after I played, I simply asked: "now it is your turn; pretend that I am playing when you play. Your sound must be exactly the same as mine." She instantly fixed not only the placement of the bow, but the bow pressure and speed as well. This type of experience has happened with many other students of mine in a variety of technical problems.

Another example of application for beginners is when working on intonation. Sometimes the teacher is tempted to simply ask the student to aim "at the tapes" on the fingerboard, which could be considered external focus since the emphasis is on the tapes. Nevertheless, the final goal should be for the student to understand that aiming at the tapes leads to good intonation and it is not just a physical location. Thus, teachers should aim to refine the students' perception of intonation instead of just instructing them on the correct physical location of the fingers on the fingerboard. The teacher could play the note to the student and ask them to achieve the same result, listening to what is different between them, for example. That does not mean that the teacher should never point to the tapes, but it is a matter of emphasis and where the focus is.

3.3.1 The sound image.

The EF2 may encompass much more than focusing on the sound of a specific bow stroke, a specific note, or a certain articulation. As students get more experienced and familiar with repertoire, style, different techniques, and the instrument itself, they further develop the sound image in their minds. The sound image is the exact mental blueprint of the desired sound. It is as if a recording is being played on the mind. It contains details about how exactly one desires, expects, or was taught to produce sound, and it involves sound concepts, nuances, style, articulations, precise pitch, dynamics, timbre, etc. It may include entire phrases, sections, and even entire movements and pieces. The more experienced the player gets, the more precise and detailed the sound image is. "Listening" to a sound or sequence of sounds in the mind is recovering the "image" of the sound that was stored in the memory.

Playing with the focus on the sound image is comparable to speaking. When we speak, we do not think about the muscles from the tongue, lips, or jaw, or on how we need to move them. We simply think of the words and those muscles are then activated automatically to produce them. In the same way, the ultimate goal when learning an instrument is to develop the highest degree of automaticity possible so that the player is capable of playing what they are thinking. This, in essence, is playing with an external focus of attention. What the motor learning literature adds is that the individual does not need to wait for the action to become automatic to start using external focus of attention. Practicing or training using EF not only enhances performance and facilitates learning, but it also accelerates the automaticity process “so that motor skills are controlled automatically, and performed with greater effectiveness and efficiency, sooner."[74]

Furthermore, directing the focus to the sound image (or simply to the desired sound) may further develop the sound image itself. Imagining exactly how one wants to sound, makes the student think deeper and helps to develop sound concepts, to refine aural skills, and to train the memory to recover that image when playing. Fischer supports this saying that “as students focus on the different qualities and components of the sound, their listening is immediately alerted and sharpened. Then, because they are listening better, every aspect of playing naturally improves quickly at the same time.”[75]

In this way, when using the sound image as the primary focus, it is imperative for it to be detailed, deliberate, and specific. Instructions like “think about the music” are too broad. The student should be encouraged to imagine the phrase or section with as much detail as possible. Then the sound image will be properly formed containing the exact type of vibrato, dynamics, phrasing, direction, color, timbre, intonation, articulation, rhythm, and so on, that the player intends to convey. Fischer adds that playing “with feeling and musical imagination” aids technical success as it “establishes, from the start, the vital principle that when you work on technique you nearly always have to do it *musically* and with inspiration, rather than only with detached mental control.”[76] Hence, once students are capable of correctly listening to the sound image in their minds, they will be better equipped to seek intentional and deliberate solutions in order to achieve the performance outcome that they desire.

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[74] Schmidt et al., *Motor Control and Learning*, Chap. 4.
[75] Fischer, *The Violin Lesson*, 1.
[76] Fischer, 1.

It is important to stress that what is being proposed in this chapter is not a complete avoidance of IF, much less EF1. The evidence supports that, at times, the student may need to receive instruction that directs the focus to the instrument, to technical aspects, and perhaps even to bodily mechanics in order to better discover how to produce the desired sound. The student is not supposed to simply think on the sound and hope for the best. However, focusing on the mechanics, or technique, should be just a temporary deviation of the main goal, which in this case is the resulting sound. Once the player finds the solution (how to cause effect), they may go back to a more distal focus (to the effect itself).

With that in mind, the student needs first to understand what the desired sound is. Listening along with demonstrations is of great help. After that, the student needs to be capable of imagining the expected sound. As students get more experience, they become better capable of imagining sound with more precision and detail. Then comes the stage of discovering how to achieve the desired result. With help from the teacher, the student will be better equipped to achieve it in a proper and efficient manner. Thus, when the student is reaching the desired sound, but performing it with a poor and inefficient technique (sometimes even to the point of a potential injury), it is imperative that the teacher step in and show the student more efficient options to achieve the same result. The refining of the sound image, and the technique to achieve it, happens continuously in an ongoing and cyclic process. Each stage influences the others (see Figure 2).

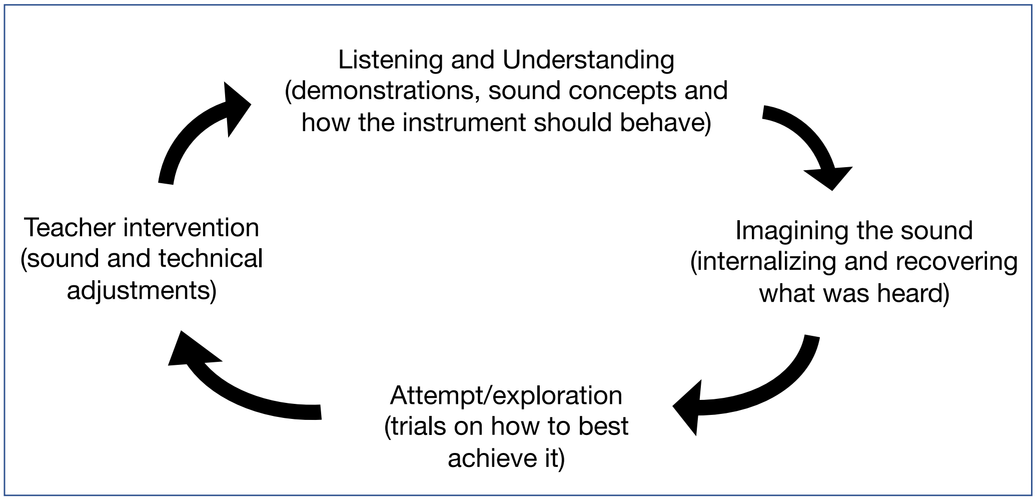

Figure 2. Ongoing cycle of learning and refining skills when using EF2.

In practical terms, the teacher's instruction could look like this: "Listen again. Do you notice that your sound is getting too heavy? Try again. It is better, but now the sound got too weak. Try to sound full but not harsh, like this, listen. Now it's your turn, try. Yes! That's better! Good! That's it! Did you hear that? The only thing now is that you are making too much effort to do it. Try the same sound, but do this, or that. Good! Always keep this sound in your mind."

When individuals maintain the focus on the cause, they might face the problem to turn the cause into the goal itself. A good example is when teaching *spiccato*. It is very common for teachers to explain every detail on how to produce the *spiccato* – how the right arm, hand, wrist, and fingers should behave, how the bow should bounce, the best region of the bow to play, etc. – but with vague or little explanation on how it should really sound. The student then tries to imitate the mechanics of the teacher paying close attention to "how" to play *spiccato*. Oddly enough, sometimes the movement looks very similar, but the sound is quite different. Then, the teacher keeps trying to look for what is wrong with the mechanics making the student try different things, but without success.

The focus, in that case, is on imitating the mechanics instead of reproducing the correct sound.

An alternative, based on a more distal EF, is for the teacher to explain and demonstrate to the student how *spiccato* should sound, first asking the student to pay attention primarily to the sound rather than on how to achieve it. The teacher may explain the mechanics as well but always remains focused on the end-product, i.e., the sound. Then, when students try to play by themselves, their focus will be on imitating the sound. In this way they have more room for self-discovery and problem-solving skills development because they are making adjustments while trying to find how to achieve the desired sound. Once the student understands the sound and its reproduction is very close to the expected result, the teacher may then give further suggestions and instructions for the student to find more efficient ways to produce it. Figure 3 shows some examples of language that may be used when teaching *spiccato* under different focal distances. Teachers should make an effort to use external focus of attention as much as possible testing different distances and focal points to see which of them is most beneficial to the student. Although IF is not always avoidable and it may actually help on some occasions, the teacher may be surprised by the learning results that the student may draw from the effort of pushing the focus externally.

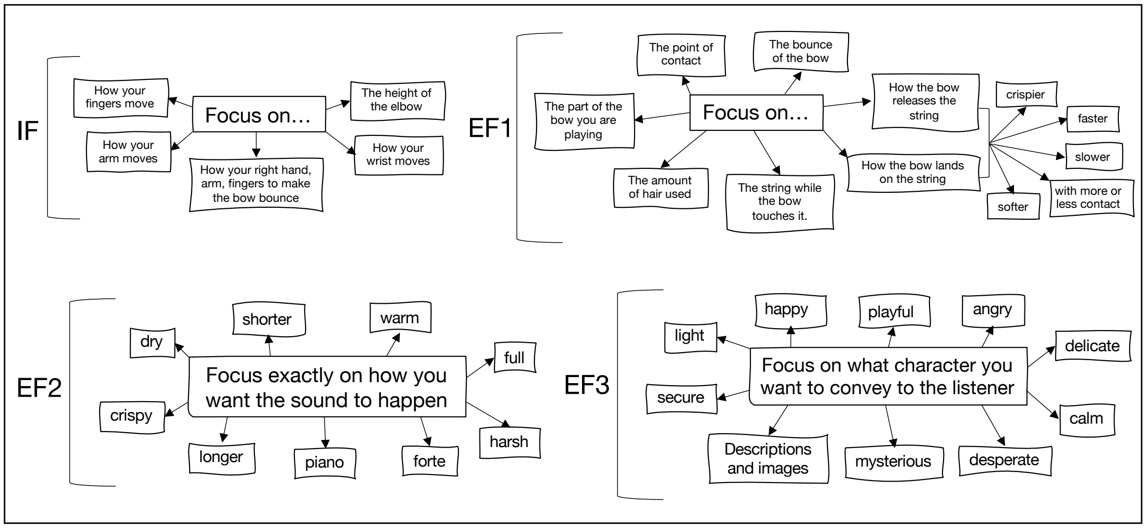

Figure 3. Examples of possible attentional foci when teaching and/or learning *spiccato* considering different focal distances.

3.4 External Focus 3: Emotional Intentions and Musical Expression

Finally, the last focal distance proposed in this classification is the focus directed to the emotional intentions or musical expression (EF3). Music has the power of portraying moods, feelings, emotions, and inspiring the imagination. The same note, phrase, or articulation can be played in a different manner producing a completely different musical expression. In this way, at a more advanced stage, the violinist may direct the focus to this farther level attending to the emotional intention or musical expression they want to convey or to the emotional impact they want to make on the audience. Some musicians call this the musical message to be delivered; a story to be told.

This type of focus will also have an impact on the other levels. The player may need to make changes and adjustments on the sound image and, consequently, on the technical aspects to achieve the desired intentions. In most cases, the body will automatically make the necessary adjustments using unconscious and reflexive processes.

For example, if the player needs a more forceful sound to portray anger, then the violinist may automatically change how they play using more pressure and/or weight on the right arm, exaggerating the accents, playing closer to the bridge, and perhaps modifying the type of vibrato. The expertise and experience of the violinist will make those adjustments happen with great flexibility and fluidity without "thinking" on how to do it.

The positive impact on performance achieved through focusing on the musical expression has support from Mornell and Wulf's study.[77] In the external focus condition, experienced players playing a piece already mastered were asked to play for the audience and to focus on the expressive sound of the music. "The musicians' performance was immediately improved with the instructions to focus on the effects of their movements (e.g., on what they expected the audience to hear)."[78]

Additionally, it may be also effective to direct the focus to something physically far from the player depending on the goal. For example, if the goal is to improve sound projection, instead of focusing on how to adjust the body movements or on how to manipulate the instrument, it may be more effective to direct the focus to a specific far point or object in the room, or to focus on delivering the sound to "the last row in the hall," or the player may focus on "filling" the entire room with sound. In most cases, the bodily adjustments will happen automatically without the need for conscious intervention.

Many musicians and pedagogues might be surprised that directing the focus externally to the sound, musical expression, and/or sound image resulting from

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[77] See Mornell and Wulf, "Adopting an External Focus of Attention Enhances Musical Performance."
[78] Mornell and Wulf, 385.

movement leads to better technical and musical results than focusing on the body movements and technical aspects themselves, even on earlier stages of learning. However, the motor learning literature is quite consistent about the benefits of EF over IF, including studies in music. Strong examples come from Mornell and Wulf's studies in which focusing on technical precision did not produce better results than focusing on the musical expression.[79]

External focus of attention seems to be more natural even in our daily activities. As with the aforementioned example of talking, walking is another way in which we may draw similar conclusions. When we walk, we do not think about how our legs should move, or to the exact angles that the knees should bend, or on how the muscles of the body should behave to keep the balance, etc. We do not need to have that at our conscious level. We simply aim for the direction that we want to go, and the body takes care of the mechanics automatically. The same reasoning can be applied to violin playing. Imagine playing the violin thinking at the conscious level of every single detail in terms of the mechanics and technique: elbow angles, wrist motion, exact behavior of arms and fingers, the correct force of the fingers in the fingerboard, correct placement of the bow, exact nuances of the bow for each type of articulation and bow stroke, etc. Given the complexity involved with playing the violin, it is impractical to think that a violinist may be able to manage each of these elements at the conscious level all at the same time.

Nonetheless, it is common for violin teachers to encourage students to try to remember primarily the feeling in their bodies or in their muscles after a successful trial.

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[79] See Mornell and Wulf, "Adopting an External Focus of Attention Enhances Musical Performance."

However, this type of feeling is more susceptible to external interferences. Trying to remember the amount of muscle force used, or how exactly it looked like in the mirror, or how exactly it felt, is very unstable. On the next day, the student might feel more tired, the muscles might be fatigued due to a workout session, the student might become dependent on the mirror if overused, etc. Moreover, in a pressure situation as in a recital, for example, it is very common for the muscles to get tighter. Focusing externally (such as on the sound image) may be much more stable and reliable because when the focus is directed to the desired effect, automatic, "unconscious, fast, and reflexive control processes"[80] will take place to adapt the technique to the new reality and find the same musical results. Thus, this approach may be more active, flexible, stable, and adaptive.

Taking into account the theoretical framework from focus of attention as presented by the motor learning literature along with its extensive experimental studies, it is reasonable to conclude that playing and teaching violin while externally directing the focus on the effects of the actions, especially on the desired resulting sound or musical intentions, activates the automated motor control processes more efficiently, may enhance learning, and may benefit performance including under pressure situations.

[80] Wulf, "Attentional Focus and Motor Learning," 91.

CHAPTER 4

PRACTICE SCHEDULES

In every practice session, violinists constantly face decisions on what to practice and how to organize their time. Sometimes attention is needed on specific passages throughout a piece, such as intonation in the opening of a concerto, string crossings in the development, chordal technique in the coda of a work, and so on. Is there a strategy that can produce better long-term learning to sequence all these different tasks? Would practicing each task, one at a time repeating it over and over until it is mastered, be most effective? Or repeating each task at the criterion level for a predetermined number of times with minimal or no mistakes? Would it be better to practice the tasks in a random order? Or a combination of both approaches? Practice schedules have received vast attention in the motor learning literature, in particular studies on blocked practice and random practice (also called interleaved practice). The resulting effect on learning from these practice schedules is called the contextual interference effect.[81]

4.1 Blocked and Random Practice Schedules

Blocked practice happens when the learner practices each task repeatedly and separately from one another. Thus, the tasks are practiced in blocks and once the practice of that task ends, the individual moves to the next one using the same approach. A violinist practices under a blocked schedule when they select an excerpt from the repertoire, for example, and repeats it over and over before moving on to the next excerpt.

[81] Schmidt and Lee, *Motor Learning and Performance*, 239.

Random practice on the other hand, happens when the learner selects a predetermined number of tasks and repeats them in random order. An example of this schedule is when the violinist selects an excerpt from the repertoire (task A), a shifting exercise (task B), and an *arpeggio* (task C), for instance, and arranges their repetitions in a random order. This schedule of practice could look like this: ACB/CBA/BAC/ABC...

Blocked practice is far more common across disciplines, including music. Generally, this is the way students learn how to practice and it is an approach frequently recommended and encouraged by many teachers. On the one hand, this makes perfect sense since the learner can focus on one task at a time, remembering each detail that needs improvement with little or no interference from practicing other tasks. Moreover, the gains in performance can usually be readily perceived (although this does not necessarily represent learning).[82] In both frequency employed by musicians and immediacy of improvement perceived therefore, blocked practice seems to be preferable over random practice.

Motor learning scientists have conducted numerous experiments in random schedule learning however, with results that challenge the long-held point of view about the superiority of strict blocked practice schedules.[83] The classic experiment that inspired

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[82] 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 et al. (New York: Worth Publishers, 2011), 57–58.

[83] For reviews see João Barreiros, Teresa Figueiredo, and Mário Godinho, "The Contextual Interference Effect in Applied Settings," *European Physical Education Review* 13, no. 2 (June 2007): 195–208, https://doi.org/10.1177/1356336X07076876; Frank Brady, "A Theoretical and Empirical Review of the Contextual Interference Effect and the Learning of Motor Skills," *Quest (National Association for Kinesiology in Higher Education)* 50, no. 3 (1998): 266–93, https://doi.org/10.1080/00336297.1998.10484285; Frank Brady, "Contextual Interference: A Meta-Analytic Study," *Perceptual and Motor Skills* 99, no. 1 (2004): 116–26,

numerous subsequent studies, was conducted by John Shea and Robyn Morgan in 1979.[84] Subjects were divided into blocked and random practice groups and were assigned three different tasks that involved rapid arm movement patterns by knocking over small wooden barriers. The goal was to perform it as fast as possible. After fifty-four trials in the acquisition phase (eighteen for each task), participants performed two retention tests and two transfer tests.[85] The results puzzled the scientists: while the blocked group outperformed the random group during the acquisition phase (as expected), there was a switch in the retention tests: the random group significantly outperformed the blocked group on retention (see Figure 4). The same trend was found for transfer tests. The conclusion was that blocked practice yields better performance during practice, but random practice may be far superior for long-term learning.[86]

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https://doi.org/10.2466/pms.99.1.116-126; Frank Brady, "The Contextual Interference Effect and Sport Skills," *Perceptual and Motor Skills* 106, no. 2 (April 2008): 461–72, https://doi.org/10.2466/pms.106.2.461-472; Timothy D. Lee, "Contextual Interference: Generalizability and Limitations," in *Skill Acquisition in Sport: Research, Theory and Practice*, ed. Nicola J. Hodges and Mark A. Williams, 2nd ed. (New York: Routledge, 2012), 79–93; Richard A. Magill and Kellie G. Hall, "A Review of the Contextual Interference Effect in Motor Skill Acquisition," *Human Movement Science* 9, no. 3–5 (1990): 241–89; as well as David L. Wright and Taewon Kim, "Contextual Interference: New Findings, New Insights, and Implications for Skill Acquisition," in *Skill Acquisition in Sport: Research, Theory and Practice*, ed. Nicola J. Hodges and Mark A. Williams, 3rd ed. (New York: Routledge, 2019), 99–118, https://doi.org/10.4324/9781351189750-6.

[84] 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): 179–87.

[85] On retention tests, they performed three trials per task in either blocked or random order. Thus, four groups resulted from retention tests: (1) blocked acquisition – blocked retention, (2) blocked acquisition – random retention, (3) random acquisition – blocked retention, and (4) random acquisition – random retention.

[86] Shea and Morgan, "Contextual Interference Effects," 186–87.

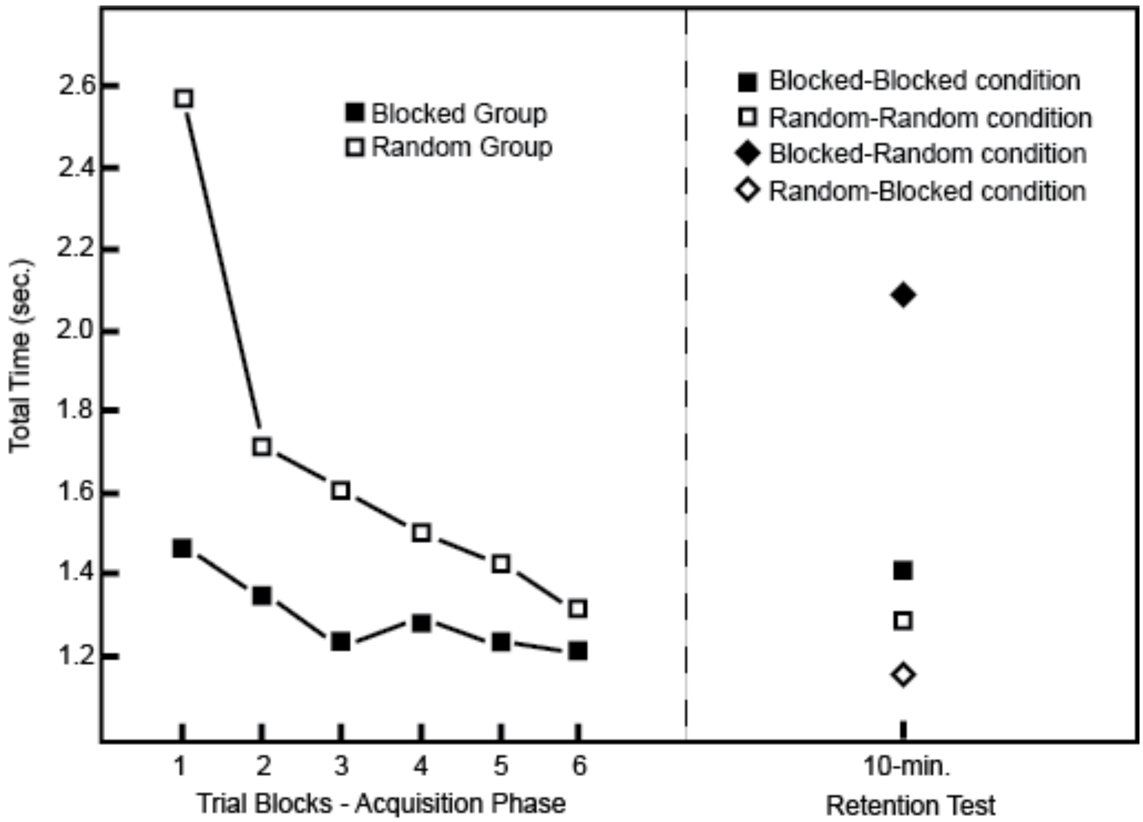

Figure 4. Results from Shea and Morgan's experiment (1979) comparing blocked and random practice schedules. Figure based on the original.

This outcome, i.e., the random condition performing worse than the blocked condition during the practice phase but outperforming the blocked condition on retention tests is understood to be due to contextual interference (CI). Randomizing the order of the repetitions across the practice session is believed to create interference in the working memory between repetitions of the same task.[87] In blocked practice, the learner experiences low levels of CI, while random practice creates high levels of CI. When better learning results from exposure to high CI, the literature calls this outcome of the

[87] Richard A. Magill and David I. Anderson, *Motor Learning and Control: Concepts and Applications*, 11th ed. (New York: McGraw-Hill Education LLC, 2016), 388.

contextual interference effect.[88] This was clearly the case in Shea and Morgan's experiment.

Subsequent experiments and research in laboratory settings have supported similar conclusions, i.e., blocked schedules tend to benefit performance during practice, while random practice benefits long-term learning.[89] Before the first studies, the general assumption among researchers was that any immediate gains on performance during practice would necessarily imply in gains on learning. However, this "performance-learning paradox" seen in those experiments led to a new debate on why this happens and a re-thinking about the motor learning process itself.[90] Theorists soon started to search for reasons why this curious phenomenon happens.

4.2 Hypotheses Behind CI Effect

One of the concepts behind the benefits of CI on learning is that higher levels of CI are believed to create higher demands on the learner and makes practice more challenging.[91] Challenging the learner in the right extent has been hypothesized to create "desirable difficulties" during practice that will further stimulate and enhance the learning process to more optimal levels.[92] According to Bjork and Bjork,[93] desirable difficulties include creating less predictable learning environments such as, among other things, alternating tasks to be learned. There are two main hypotheses that explain the internal mechanisms behind the CI effect: the elaboration hypothesis, proposed by Shea

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88 Magill and Anderson, 389.
89 See Magill and Hall, "A Review of the Contextual Interference Effect."
90 Schmidt et al., *Motor Control and Learning*, chap. 10.
91 Wright and Kim, "Contextual Interference," 115.
92 Bjork and Bjork, "Making Things Hard on Yourself, but in a Good Way," 57–58.
93 Ibid., 58.

and colleagues,[94] and the forgetting and reconstruction hypothesis (or action plan reconstruction hypothesis), proposed by Lee and Magill.[95]

The forgetting and reconstruction hypothesis holds that random practice causes a temporary forgetting of each task's action plan due to the constant shifting of tasks. For each action, the individual needs to generate or retrieve an action plan or a task solution. When exposed to random practice, the learner is forced to constantly forget and reconstruct this task solution, which is believed to strengthen the retrieval processes as well as the long-term memory. In this way, the learner can more easily retrieve the learned skill. In other words, it is the effort of constantly retrieving the information that makes learning more effective. In blocked practice, the individual simply reproduces the action plan that is already in working memory. This may well explain the reason for the enhanced performance during acquisition in most studies for the blocked practice condition when compared to the random practice.[96]

The elaboration hypothesis, on the other hand, explains that random practice gives more opportunity for comparison and contrast between tasks, which better elaborates the memory representations of the skill when compared to blocked practice. As the learner frequently switches tasks in the random schedule, the working memory houses them simultaneously, which in turn, gives the learner the opportunity of constantly comparing

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[94] Shea and Morgan, "Contextual Interference Effects"; John B. Shea and Robert C. Titzer, "The Influence of Reminder Trials on Contextual Interference Effects.," *Journal of Motor Behavior* 25, no. 4 (1993): 264–74, https://doi.org/10.1080/00222895.1993.9941647.

[95] Timothy D Lee and Richard A Magill, "The Locus of Contextual Interference in Motor-Skill Acquisition," *Journal of Experimental Psychology. Learning, Memory, and Cognition* 9, no. 4 (1983): 730–46, https://doi.org/10.1037/0278-7393.9.4.730; Timothy D. Lee and Richard A. Magill, "Can Forgetting Facilitate Skill Acquisition?," in *Advances in Psychology*, ed. David Goodman, Robert B. Wilberg, and Ian M. Franks, vol. 27 (Amsterdam: Elsevier, 1985), 3–22, https://doi.org/10.1016/S0166-4115(08)62528-5.

[96] Schmidt et al., *Motor Control and Learning*, chap. 10.

and contrasting their similarities and differences, even subconsciously. This process is believed to strengthen, enrich, and turn the memory more meaningful, while at the same time providing important cues that will help the retrieval process of the skill, thus promoting better long-term memory.[97] In contrast, when in blocked practice, the learner has less opportunity for such elaboration since the tasks are practiced in isolation from one another. Schmidt et al. point out many studies supporting both hypotheses. He states that although neither of these theories can fully explain all the details and findings that exist up to date, "the hypotheses should not necessarily be seen as competing predictors of the CI effect, but perhaps rather as complementary theoretical views about the ways in which learners comply with the processing operations encouraged under different practice and task conditions."[98]

4.3 Generalization of the CI Effect

As mentioned earlier, the generalizability of the CI effect is quite robust in laboratory settings in a variety of different types of tasks.[99] The debate on whether these results would be replicated in applied settings and real-world tasks led to numerous additional studies.[100] One of the first experiments in applied settings was conducted by Goode and Magill testing badminton serves.[101] Participants with no badminton or racket sports experience practiced three times a week for three weeks, training three different types of serves. One group was exposed to blocked practice and the other to random

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[97] Edwards, *Motor Learning and Control*, 410.
[98] Schmidt et al., *Motor Control and Learning*, chap. 10.
[99] See Magill and Hall, "A Review of the Contextual Interference Effect."
[100] See Brady, "A Theoretical and Empirical Review of the Contextual Interference Effect"; and Brady, "The Contextual Interference Effect and Sport Skills."
[101] Sinah Goode and Richard A. Magill, "Contextual Interference Effects in Learning Three Badminton Serves," *Research Quarterly for Exercise and Sport* 57, no. 4 (December 1986): 308–14, https://doi.org/10.1080/02701367.1986.10608091.

practice. Results were very similar to Shea and Morgan's study, i.e., blocked schedule seemed advantageous during practice, however on retention and transfer tests the random practice group outperformed the blocked practice group.

Another seminal study in applied settings is an experiment made with skilled young baseball players by Hall, Domingues, and Cavazos.[102] Over a period of six weeks of practice, participants hit three different types of pitches repeating each of them fifteen times in each training session in either random or blocked schedules. Results during acquisition and retention phases showed the same trends observed in the previously discussed experiments with a large advantage for the random group on retention. Similar outcomes were found in numerous other applied setting studies as well, including volleyball,[103] tennis,[104] kayaking,[105] golf,[106] snowboarding,[107] research with badminton skills,[108] children practicing handwriting,[109] and, as discussed in more detail later, in

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[102] Kellie G. Hall, Derek A. Domingues, and Richard Cavazos, "Contextual Interference Effects with Skilled Baseball Players," *Perceptual and Motor Skills* 78, no. 3 (June 1994): 835–41, https://doi.org/10.1177/003151259407800331.
[103] Laura Bortoli et al., "Effects of Contextual Interference on Learning Technical Sports Skills," *Perceptual and Motor Skills* 75, no. 2 (October 1992): 555–62, https://doi.org/10.2466/pms.1992.75.2.555.
[104] Hector Hernández-Davo et al., "Variable Training: Effects on Velocity and Accuracy in the Tennis Serve," *Journal of Sports Sciences* 32, no. 14 (August 27, 2014): 1383–88, https://doi.org/10.1080/02640414.2014.891290.
[105] Peter J.K. Smith and Marianne Davies, "Applying Contextual Interference to the Pawlata Roll," *Journal of Sports Sciences* 13, no. 6 (December 1, 1995): 455–62, https://doi.org/10.1080/02640419508732262.
[106] Jared M. Porter et al., "The Effects of Three Levels of Contextual Interference on Performance Outcomes and Movement Patterns in Golf Skills," *International Journal of Sports Science & Coaching* 2, no. 3 (September 2007): 243–55, https://doi.org/10.1260/174795407782233100.
[107] Peter J K Smith, "Applying Contextual Interference to Snowboarding Skills.," *Perceptual and Motor Skills* 95, no. 3 Pt 1 (December 2002): 999–1005.
[108] Craig A. Wrisberg and Zhan Liu, "The Effect of Contextual Variety on the Practice, Retention, and Transfer of an Applied Motor Skill," *Research Quarterly for Exercise and Sport* 62, no. 4 (December 1991): 406–12, https://doi.org/10.1080/02701367.1991.10607541; Daniel Memmert et al., "Conditions of Practice in Perceptual Skill Learning," *Research Quarterly for Exercise and Sport* 80, no. 1 (March 2009): 32–43, https://doi.org/10.1080/02701367.2009.10599527.
[109] Diane M. Ste-Marie et al., "High Levels of Contextual Interference Enhance Handwriting Skill Acquisition.," *Journal of Motor Behavior* 36, no. 1 (March 2004): 115–26.

music.[110] Moreover, other experiments extended these findings to individuals with disabilities, clinical settings like surgical skill training, and other types of skill such as foreign language learning, and logic operations.[111]

4.4 Experiments in Music

Some recent studies have explored the effects of contextual interference in musical settings; however, they are not as conclusive. Laura A. Stambaugh conducted a series of experiments with both novice and experienced wind musicians playing a simple seven note sequence. Participants were asked to play it as accurately, evenly, and fast as possible, measuring the variables of accuracy, speed, and evenness. In her first experiment,[112] she found better speed results in the twenty-four-hour retention test for beginner children playing the clarinet in the random condition, compared to the blocked group. Although there was no difference in accuracy and evenness between the random and blocked groups, children in the random practice group could play significantly faster without losing accuracy. Similarly, speed and evenness were also superior in the twenty-four-hour retention test for undergraduate woodwind concert band students that utilized random practice in a further study.[113]

In the same study, however, brass players in the blocked condition got better accuracy and speed in the twenty-four-hour retention test than their counterparts in the random condition. Nonetheless, when comparing performance between phases within the

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[110] Laura A. Stambaugh, "When Repetition Isn't the Best Practice Strategy: Effects of Blocked and Random Practice Schedules," *The National Association for Music Education* 58, no. 4 (January 2011): 368–83, https://doi.org/10.1177/0022429410385945.
[111] See Soderstrom and Bjork, "Learning Versus Performance"; Lee, "Contextual Interference: Generalizability and Limitations"; and Wright and Kim, "Contextual Interference."
[112] Stambaugh, "When Repetition Isn't the Best Practice Strategy."
[113] Laura A. Stambaugh, "Differential Effects of Cognitive Load on University Wind Students' Practice," *Psychology of Music* 41, no. 6 (November 2013): 749–63, https://doi.org/10.1177/0305735612449505.

same groups, both woodwind and brass players from the random practice group could maintain generally the same levels of speed and accuracy they achieved at the end of acquisition when they performed the retention test. Even at the one-week retention test, the players maintained a consistent level. On the other hand, in the blocked condition, both woodwind and brass players lost speed when performing the two retention tests compared to the score they received at the end of the acquisition phase. This was especially true for the brass players, who significantly dropped their speed on both retention tests.

In another study, Stambaugh selected subjects with different levels of expertise (novice, intermediate, and advanced) to perform in a woodwind MIDI instrument.[114] Although there were no significant differences between conditions for pitch accuracy on the retention test, evidence for a trend for speed was demonstrated: in the blocked condition, players tended to lose speed in the twenty-four-hour retention test, while in the random condition, players tended to gain speed without compromising accuracy. This was more evident in the novice players.

Based on these studies, it is possible to draw a general initial conclusion: as with studies in other fields, blocked practice in music tends to create an illusion of actual learning progress. The participants in the blocked condition that practiced at certain speeds during the acquisition phase, maintained accuracy on the next day, but at the expense of speed. On the other hand, participants in the random practice condition, after achieving a certain speed at the end of the acquisition phase, could maintain both

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[114] Laura A. Stambaugh, "Implications of Extrinsic Cognitive Load on Three Levels of Adult Woodwind Players," *Psychology of Music* 44, no. 6 (November 2016): 1318–30, https://doi.org/10.1177/0305735615627206.

accuracy and speed levels on the next day and, in some cases, even demonstrated an increase in speed without compromising accuracy. These findings are significant, especially when taking into consideration the principle of speed-accuracy trade-off which states that when speed increases, there is a tendency for accuracy to decrease and vice-versa.[115]

In a study, conducted by Stambaugh and Demorest,[116] they selected middle school kids who played either the saxophone or the clarinet. Participants had one to three years of experience and were given the task to play three simple melodies of eight measures duration. The results showed no significant difference between groups in either phase, but there is a very plausible explanation. The maximum score for all three tasks together was three hundred points (one hundred points each). The data revealed that participants had a mean score of 286.06 points, a very high score. Although there was an attempt by the researchers to match the task difficulty with the skill level of the participants, the scores indicated that the task was very easy for them, which possibly made of little effect the way in which they practiced (this was acknowledged by the researchers themselves).[117] This can be illustrated by an example in which a professional violinist is asked to practice a Suzuki Book 1 level piece in either blocked or random order. The practice schedule will hardly make a significant difference in the final result in this case as the violinist will undoubtedly play the piece at a high level even when sight-reading it. Although this is an extreme case for experimental purposes, it illustrates the point that the difficulty level of

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115 Schmidt et al., *Motor Control and Learning*, chap. 7.
116 Laura A. Stambaugh and Steven M. Demorest, "Effects of Practice Schedule on Wind Instrument Performance: A Preliminary Application of a Motor Learning Principle," *The National Association for Music Education* 28, no. 2 (May 2010): 20–28, https://doi.org/10.1177/8755123310361768.
117 Stambaugh and Demorest, 25–26.

the task must be challenging enough for the participants, so that they can show significant differences in their respective conditions in order for the researchers to draw more solid conclusions.

Finally, another study with musical tasks utilized a more ecological approach than the previously discussed studies. Carter and Grahn[118] selected advanced clarinetists and asked them to practice a concerto exposition and a technical excerpt in a blocked practice fashion spending twelve minutes per piece. The same participants (within subject design) were asked to practice another concerto exposition and another technical excerpt in a random practice order, alternating three minutes each piece until they achieved a total of twelve minutes per piece. Three blind judges evaluated the performance recordings of each participant and gave scores for three different stages: the sight-reading, the run-through at the end of acquisition, and the run-through at the retention test that took place on day two of the experiment.

The results showed that, overall, whenever there was a difference in the scores between conditions, it favored the random condition. A questionnaire with participants at the end of the study also revealed that random schedule led to positive strategies such as goal settings, mistake identification, and focus. It is important to notice that the participants were compared to themselves, since it was adopted a within subject design. This minimizes possible interference in the results with differences in skill level, previous experience, and individuality between subjects. The study would have been even more valuable if they had adopted a more precise scoring system, as it asked for the evaluators

[118] 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 18, 2016), https://doi.org/10.3389/fpsyg.2016.01251.

to base the scores just on the overall performance considering accuracy, technique, and musicality altogether, rather than giving separate scores for each specific category.[119] Nevertheless, the experiment gives good insight on possible ways to apply practice schedules in musical settings as well as provides further evidence of the advantages of using random practice even in music.

4.5 Factors that Influence the Contextual Interference Effect

Even with a wide range of studies supporting the CI effect in both laboratory and applied settings, there are some experiments in applied settings that found little or no superior learning effects of random over blocked practice on retention and transfer. Some researchers even suggest that findings in applied settings are not as strong and consistent as research in laboratory.[120] In light of that, researchers started to look for possible reasons and patterns in order to explain these results and, most importantly, to find a more solid base to give directions to practitioners, instructors and teachers on how to apply CI in their respective fields. The main investigations involve task characteristics (such as skill complexity and task differences) and learner characteristics (such as learner's age and skill level).

When considering task characteristics, Magill and Anderson speculate two reasons for some discrepancies in results between laboratory research and applied setting studies.[121] The first refers to the amount of practice employed in the experiments which no effect was found. The learning of skills in applied settings, like sports, usually requires

[119] Carter and Grahn, 5.
[120] See Barreiros, Figueiredo, and Godinho, "The Contextual Interference Effect in Applied Settings"; Brady, "Contextual Interference: A Meta-Analytic Study"; and Brady, "The Contextual Interference Effect and Sport Skills."
[121] Magill and Anderson, *Motor Learning and Control*, 395.

more practice due to its complexity and difficulty. Thus, they argue that there was not enough practice in those cases to properly investigate CI. The second reason states that skills from applied settings may have unique characteristics that need different amounts of CI in its different stages of learning. Hence, it seems that task difficulty and complexity may modulate CI effects.

The age and skill level of the learner may also play a role. Although there is evidence that children benefit from high amounts of CI,[122] there is also evidence that it does not add any advantage.[123] In fact, Coker affirms that, in general, lower levels of CI (i.e., towards blocked practice fashion) may be more beneficial for children.[124] This view is also supported by Brady in his literature review.[125] Likewise, studies have shown that novices tend to benefit more from lower levels of CI as well.[126] Coker provides a possible explanation, stating "given that a high degree of cognitive processing is needed during the initial stage of learning in order to develop an understanding of the movement, it is likely that the elevated level of interference created by random practice conditions simply overwhelms the learner."[127]

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[122] Ste-Marie et al., "High Levels of Contextual Interference Enhance Handwriting Skill Acquisition."; G Wulf, "The Effect of Type of Practice on Motor Learning in Children," *Applied Cognitive Psychology* 5, no. 2 (March 1, 1991): 123.
[123] See Brady, "Contextual Interference: A Meta-Analytic Study."
[124] Coker, *Motor Learning and Control for Practitioners*, 272.
[125] Brady, "A Theoretical and Empirical Review of the Contextual Interference Effect," 285.
[126] For examples see Patricia Del Rey, Michael Whitehurst, and Judith M. Wood, "Effects of Experience and Contextual Interference on Learning and Transfer by Boys and Girls," *Perceptual and Motor Skills* 56, no. 2 (April 1983): 581–82, https://doi.org/10.2466/pms.1983.56.2.581; as well as Edward P. Hebert, Dennis Landin, and Melinda A. Solmon, "Practice Schedule Effects on the Performance and Learning of Low- and High-Skilled Students: An Applied Study," *Research Quarterly for Exercise and Sport* 67, no. 1 (March 1996): 52–58, https://doi.org/10.1080/02701367.1996.10607925.
[127] Coker, *Motor Learning and Control for Practitioners*, 273.

4.5.1 The challenge framework

The relation between task characteristics and learner characteristics is in line with the challenge framework proposed by Guadagnoli and Lee.[128] They argue that nominal task difficulty (which reflects the difficulty and complexity of the task itself without considering the learner's level) and functional task difficulty (the difficulty as a function of the learner's skill level) may influence the effects of contextual interference. Lower nominal difficulties (task characteristics) as well as lower functional difficulties (learner's level) seem to benefit more from higher levels of CI (towards random practice) and vice-versa (see Figure 5). Thus, if the challenge (difficulty) is too high for that learner due to either their level or the task itself, the addition of CI may overwhelm the learner. On the other hand, when the task is very complex and difficult, but the individual is advanced, the functional difficulty significantly decreases for that person, and they receive more benefits from high CI than from low CI.[129] A possible solution is systematically increasing the amounts of CI as the learner gets more proficient.[130]

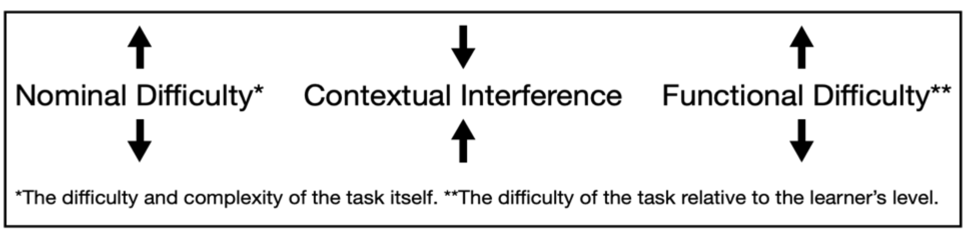

Figure 5. Optimal challenge points and the relationship between contextual interference and nominal and functional difficulty based on the challenge framework proposed by Guadagnoli and Lee (2004).

[128] Mark A. Guadagnoli and Timothy D. Lee, "Challenge Point: A Framework for Conceptualizing the Effects of Various Practice Conditions in Motor Learning," *Journal of Motor Behavior* 36, no. 2 (July 2004): 212–24, https://doi.org/10.3200/JMBR.36.2.212-224.
[129] Guadagnoli and Lee, 218–19.
[130] Magill and Anderson, *Motor Learning and Control*, 395.

It is important to observe that although some experiments show similar levels of performance in both groups on retention, when there is a difference, it almost always favors the random practice and only rarely does the blocked practice group outperform the random practice group on retention.[131] Moreover, superior performance for random practice learners were shown in some experiments also during the acquisition phase, especially in applied settings.[132] This indicates that the potential disadvantage of random schedules during the practice phase may not be so concerning. However, hybrid practice schedules may be a better alternative to get the best of both approaches.

4.6 Hybrid Schedules

As research suggests that different circumstances require different levels of CI, it may be very effective to implement schedules that combine characteristics from both random and blocked fashion: the hybrid schedules. In fact, practice schedules should not be limited to strict random practice in which there are never (or almost never) consecutive repetitions of the same task, or to strict blocked practice when each task is repeated separately in blocks with almost no interleaving practice of other tasks. Rather, contextual interference levels may be viewed as a continuum between these two extremes.

Along the continuum, there are hybrid schedules that combine these two approaches resulting in moderate amounts of CI (see Figure 6). For example, serial

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[131] Schmidt et al., *Motor Control and Learning*, chap. 10.

[132] For example, Dennis Landin and Edward P. Hebert, "A Comparison of Three Practice Schedules along the Contextual Interference Continuum," *Research Quarterly for Exercise and Sport* 68, no. 4 (December 1997): 357–61, https://doi.org/10.1080/02701367.1997.10608017; Jared M. Porter and Richard A. Magill, "Systematically Increasing Contextual Interference Is Beneficial for Learning Sport Skills," *Journal of Sports Sciences* 28, no. 12 (October 2010): 1277–85, https://doi.org/10.1080/02640414.2010.502946; Esmaeel Saemi et al., "Practicing Along The Contextual Interference Continuum: A Comparison of Three Practice Schedules in an Elementary Physical Education Setting," 2012, 191–98.

practice arranges the random repetitions in a predictable order (e.g., ABC/ABC/ABC…) lowering, in theory, the levels of CI.[133] Another option is to create mini-blocks of repetitions, executing them in either serial or random order (e.g., AAA BBBCCC/ AAABBBCCC/AAABBBCCC… or AAACCCBBB/CCCBBBAAA/BBBAAA CCC…). This approach, called random-blocked practice or repeated blocked practice,[134] creates even more moderate levels of CI. Hence, it is possible to regulate the amount of CI by changing the number of practice trials within each mini-block of practice. Increasing the number of repeated trials of the same task, lowers the levels of CI and vice-versa. These alternatives open numerous possible combinations.

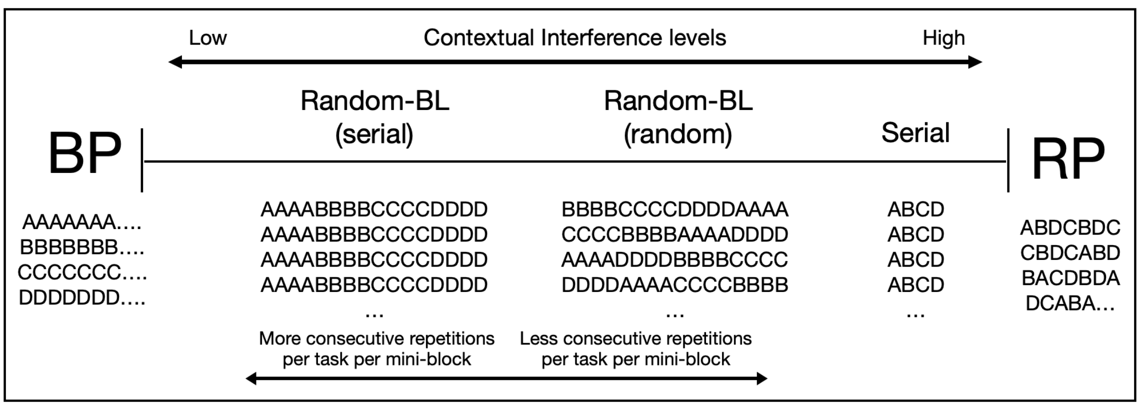

Figure 6. Different practice schedules along the contextual interference continuum.

In order to investigate hybrid schedules, Landin and Hebert[135] selected thirty undergraduate students with two years of high school basketball experience to test basketball set shots from six different positions. They were divided into blocked, serial-blocked, and serial schedule groups. During acquisition, there were no significant differences among groups; however, on the retention test, the serial-blocked group

[133] Edwards, *Motor Learning and Control*, 408.
[134] Coker, *Motor Learning and Control for Practitioners*, 273.
[135] Landin and Hebert, "A Comparison of Three Practice Schedules along the Contextual Interference Continuum."

significantly outperformed the other two, favoring the hybrid schedule. A different design was conducted by Prahl and Edwards in an experiment with 112 kids from seventh grade to learn pickle-ball skills.[136] Along with the traditional blocked and random groups, they created a third group that practiced under blocked schedule in the beginning but switched to random practice midway through the study. The mixed group showed significantly greater improvements in retention than the other two groups. Similar examples are the studies from Porter and colleagues.[137]

Gradual increases of CI seem to also be beneficial to children. Studies with children performing throwing tasks[138] and karate skills[139] found superior learning and transfer for the groups that experienced increasing levels of CI compared to those children in the traditional blocked and random groups. One reason pointed out by Porter and Saemi[140] for the benefits of schedules that gradually increase CI is that it challenges the individual at the appropriate level as they become more proficient.

While there are relatively few studies that investigate alternative schedules, it seems that they are able to demonstrate the same (or even better) long-term learning

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[136] Brian. K. Prahl and William H. Edwards, "A Field Test of Contextual Interference Effects on Skill Acquisition in Pickle-Ball with Seventh-Grade Boys and Girls," abstract, *Research Quarterly for Exercise and Sport* 66, no. sup 1 (1995): A-15, https://doi.org/10.1080/02701367.1995.10608846.

[137] Porter and Magill, "Systematically Increasing Contextual Interference Is Beneficial for Learning Sport Skills"; Jared M. Porter and Trey Beckerman, "Practicing with Gradual Increases in Contextual Interference Enhances Visuomotor Learning," *Kinesiology* 48, no. 2 (2016): 244–50, https://doi.org/10.26582/k.48.2.5; Saemi et al., "Practicing Along The Contextual Interference Continuum: A Comparison of Three Practice Schedules in an Elementary Physical Education Setting."

[138] Saemi et al., "Practicing Along The Contextual Interference Continuum: A Comparison of Three Practice Schedules in an Elementary Physical Education Setting."

[139] Fateme Mohammadhasani, Robabeh Rostami, and Majid C. Cheric, "The Effect of a Combined Practice Course of Mental and Physical Practice with Systematic Increase in Contextual Interference on Learning a Kata Skill," *Annals of Applied Sport Science* 5, no. 2 (July 1, 2017): 73–80, https://doi.org/10.18869/acadpub.aassjournal.5.2.73.

[140] Jared M. Porter and Esmaeel Saemi, "Moderately Skilled Learners Benefit by Practicing with Systematic Increases in Contextual Interference," *International Journal of Coaching Science* 4 (June 1, 2010): 69.

benefits as strict random schedules, while at the same time enhancing performance levels comparable to strict blocked schedules during acquisition (or practice). Furthermore, using hybrid schedules may be a solution for a problem that might appear when using either very high or very low amounts of CI. When exposed to a pure random practice, the learner may get discouraged because it may be more difficult to perceive real progress on learning, as evidenced by some previously discussed experiments.[141] On the other hand, blocked practice might create a false sense of progress about the learning process.

In a study by Simon and Bjork,[142] participants were asked to estimate their retention performance scores right before taking the retention test. The results demonstrated that subjects who had previously practiced under the random schedule estimated poorer performances than the actual results indicated. In contrast, subjects on the blocked practice group overestimated their performance, showing that they thought they had learned much more than they actually had. This can lead to two different conclusions: high levels of CI might lead to demotivation, while low levels of CI might create an illusion of confidence leading to frustration when performing in the next day. Hybrid schedules may well be a middle ground to prevent this issue.[143] Bjork adds that "the fact that blocked practice leads to better short-term performance but poor long-term learning has great potential to fool teachers, trainers and instructors [….] It's natural to think that when we're making progress, we're learning, and when we're struggling and

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[141] See Goode and Magill, "Contextual Interference Effects"; Hall, Domingues, and Cavazos, "Contextual Interference Effects with Skilled Baseball Players."
[142] Dominic A. Simon and Robert A. Bjork, "Metacognition in Motor Learning," *Journal of Experimental Psychology. Learning, Memory, and Cognition* 27, no. 4 (2001): 907–12, https://doi.org/10.1037/0278-7393.27.4.907.
[143] Schmidt and Lee, *Motor Learning and Performance*, 246.

making errors, we're not learning as well. So people who are responsible for training can often be pushed toward training conditions that are far from optimal."[144]

The motor learning literature has shown a trend that has been frequently seen in the practice room. Violin players, regardless of their level, after repeating a given passage countless times in the previous day, often get puzzled wondering why their performance levels of that passage dropped significantly in the next day of practice. Some even feel as if they have not practiced at all the day before. The graphic from Shea and Morgan's experiment is very emblematic (see Figure 4). The data from the blocked practice participants precisely illustrates this experience. It is astonishing to observe that the levels of their performance on retention dropped almost to the same levels as at the beginning of the practice phase. On the other hand, in the random practice group, the performance levels actually increased significantly.

As widely discussed in this chapter, this trend has been frequently replicated in many other studies, including experiments in music. This should at least make one reflect if recommendations like "repeat this exercise five (or even ten!) times with no mistakes before moving to the next one" are actually the most effective recommendation. The next chapter discusses some approaches, suggestions, and recommendations that teachers and students can use to apply different practice schedules in their teaching and practice routines.

[144] Edwards, *Motor Learning and Control*, 408.

CHAPTER 5

PRACTICE SCHEDULES APPLIED TO VIOLIN PEDAGOGY

As seen in the previous chapter, the traditional blocked practice fashion may not be the most effective way of practice, especially for long-term learning. Strategic manipulation of the amounts of contextual interference may lead to a positive impact on long-term retention. However, the questions that remain are how soon it should be introduced, how much, and how exactly to apply it in practice and/or in instruction sessions. Although there is not yet a conclusive answer from the literature for either question, motor learning researchers offer guidelines based on the most up-to-date literature available. In light of that, this chapter provides suggestions on how to apply contextual interference principles to violin pedagogy. Along with the motor learning literature background, these suggestions and recommendations are also based on anecdotal evidence from my teaching experience and from my own violin practice, aiming to give initial thoughts and general guidelines to both teachers and students. It is important to emphasize that contextual interference manipulation does not undermine the importance of repetition in practice; rather, it concerns how repetition is planned. In fact, repetition is very important. Perhaps the most important factor when learning a skill.

There are several different ways that random practice can be applied to violin practice and teaching. One of them is applying a pure random schedule in either serial or random order. These are the most common schedules used in studies that investigate practice schedules, especially in the earlier ones. In this approach, the violinist selects a number of tasks to be practiced and, instead of repeating them several times consecutively (blocked practice), they play each task only one time in each round along several rounds. For example, if the number of tasks is four (A, B, C, and D) and one wants to repeat each of them ten times, then instead of repeating them in a blocked fashion (A-10x, B-10x, C-10x, D-10x), the player practices them in either random (ABCD/ACDB/CBDA… ten rounds) or serial order (ABCD-10x).

According to the motor learning literature, this approach yields better results on long-term learning than the traditional blocked practice for most cases. However, using pure random or serial schedules in the practice room might not be so pleasant. It might lead to underestimation of the real progress[145] and, the fact that one cannot repeat the task at least one or two more times to try it again right away, might seem very unsatisfying and bothersome to many. Furthermore, the highest levels of CI may not be optimal for every individual in every circumstance. Skill level, age, and task difficulty (whether nominal or functional) are believed to require different levels of CI for optimal learning.[146] Thus, as discussed in the previous chapter, using hybrid schedules to manipulate CI levels is a great alternative. Figure 7 shows examples of various practice schedules along the continuum when selecting three tasks to practice, repeating each of them twelve times.

Additionally, the motor learning literature suggests that the order on how the tasks are repeated influences the amount of CI. In theory, random order (ACB/BAC/BCA) generates higher CI levels than serial order (ABC/ABC/ABC) because the former is more unpredictable than the latter. With serial order it is easier to keep track of the repetitions and the rounds; however, one may want to use random order to generate more

[145] See Simon and Bjork, "Metacognition in Motor Learning."
[146] Guadagnoli and Lee, "Challenge Point," 219.

unpredictability and to train better the brain to retrieve, reconstruct, or elaborate the information.[147]

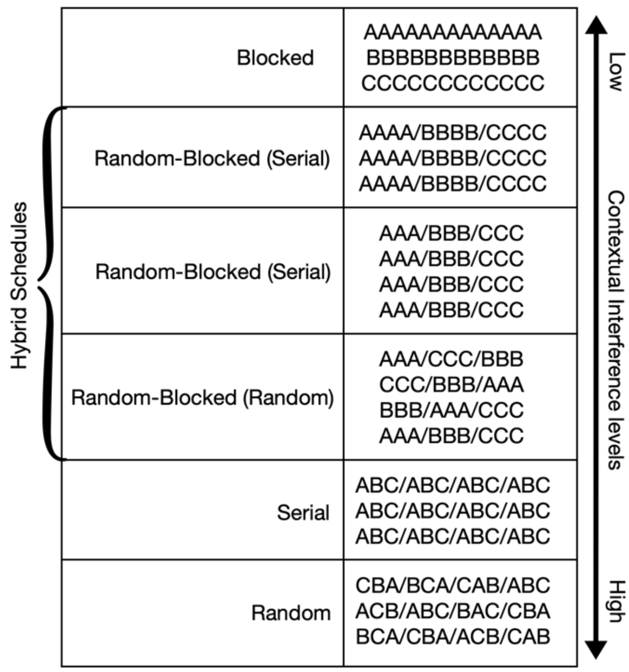

Figure 7. Examples of various practice schedules when selecting three tasks (A, B, and C) to be repeated twelve times. As an example, these tasks could be A – a three octaves scale in D major playing *spiccato*; B – four specific measures from Sibelius violin concerto movement I; C – four specific measures from Sibelius violin concerto movement III.

5.1 Applying Hybrid Schedules: The NR and T Approach

In the previous chapter, it was concluded that hybrid schedules may be very effective for CI manipulation in applied settings because they have the potential of combining the benefits of both random and blocked practice schedules, as well as meeting the learners at their individual needs. A very accessible strategy to implement in the practice room is using mini-blocks of practice, i.e., using the random-blocked

[147] See section 4.2 Hypotheses Behind CI Effect.

practice. Taking this into account, two approaches systematized and suggested in this research paper are the Time approach (T) and the Number of Repetitions approach (NR).

Both approaches are treated very similarly, but NR establishes a predetermined number of repetitions per task in each mini-block of practice and T establishes a predetermined amount of time per mini-block of practice per task. For example, if the player chooses the NR approach, they might select three tasks to practice (A, B, and C), and plan to repeat each task twelve times. In this example, the practice could be organized in four rounds of A-3x, B-3x, C-3x in either serial or random order (see third and fourth lines on Figure 7). If the T approach is selected, then the practice could have three or four rounds of A-3min, B-3min, C-3min in either serial or random order. The former is the approach most frequently used in studies that investigate hybrid schedules; the latter was used by Carter and Grahn to investigate CI with advanced clarinetists.[148] Notice that in the T approach the variable does not depend on the number of repetitions, while the NR approach does not stipulate any amount of time.

Regardless of the choice, it is advisable not to practice a large number of tasks in each round. Although the number can vary depending on the case, three to six tasks is a good recommendation, especially in the beginning when the individual is getting acquainted with CI manipulation. It is also important to repeat the mini-blocks for at least three rounds. The process of identifying the tasks that need to be practiced, or the ones that need to be prioritized, is beyond the scope of this paper, but in general, it should be based on the individual's own experience and on the teacher's recommendations. A step-

[148] Carter and Grahn, "Optimizing Music Learning."

by-step summary on how to apply these approaches in the practice room is found in Appendix A.

The tasks chosen can be classified as either related or unrelated material. For example, if the player chooses three different passages from the same movement or piece, or if they take three or four different scales or *arpeggios*, they can be classified as related material tasks. On the other hand, if the player chooses a scale, a passage from a slow movement of a Bach solo sonata, and a passage from a fast movement of a Prokofiev violin sonata, for example, those may be considered unrelated material.

Since there is no definite answer from the motor learning literature if practicing related or unrelated material leads to different outcomes on learning, the violinist may choose whatever way feels more comfortable and that suits better their needs. It is important however for the player to be specific and deliberate on the task choices. Selecting an entire long movement as a task using T, for instance, may not be appropriate because the movement may be longer than the block itself. Thus, for both NR and T it would be wise to select well-defined passages, perhaps a theme from the exposition, a portion of the development, a technically difficult passage, a scale, a Sevcik exercise, a challenging shifting, a specific bow stroke, a challenging string crossing passage, etc. In this way, it will be easier to keep track of what is being practiced.

5.1.1 Applying the Time approach (T)

When choosing T, the amount of time should not be so short that the player can hardly repeat the tasks, but it should not be so long that it does not create enough CI. Selecting between one to three minutes per mini-block is a good choice. Depending on the case, one can choose longer blocks such as five minutes. The challenge framework[149] may be of great help when selecting the amount of time: for optimal amounts of CI, the lower the nominal and/or functional difficulty of the task, the lower the amount of time per task per round is needed and vice versa (see Figure 8). Controlling it with a timer is essential.

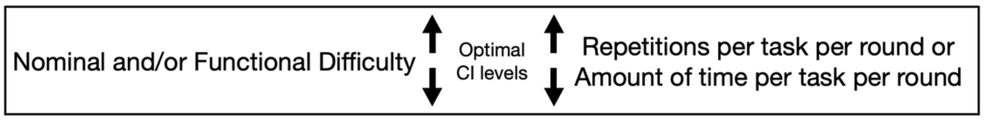

Figure 8. Relationship between nominal and/or functional task difficulty and the number of repetitions or amount of time per task per round for optimal levels of CI.

If the practice time is limited, the player must have in mind that choosing longer blocks potentially reduces the number of rounds and, consequently, the CI (see T on Figure 9). For example, if the individual selects three tasks and each one is practiced for five minutes, then after thirty minutes of practice the player will have practiced only two rounds. Revisiting the task in more rounds is essential for the random practice principle.

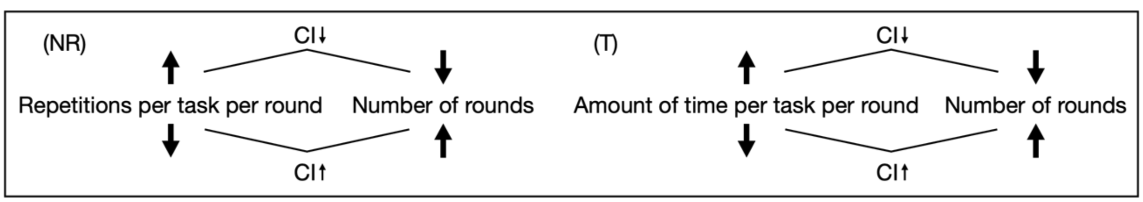

Figure 9. Different amounts of time or consecutive repetitions when using the T or NR approach potentially impact the number of rounds in a given practice session and are directly related with contextual interference levels.

In the beginning, while the learner is gaining experience with hybrid schedules, a guideline of what I call the “rule of three”, may be very useful: three tasks, three minutes each, three rounds, three minutes of rest; total is thirty minutes. In the next thirty minutes

[149] See Guadagnoli and Lee, “Challenge Point.”

the player may select other three tasks, or if needed, select the same previous three tasks (see Appendix A).

The study from Carter and Grahn,[150] discussed in the previous chapter, gives further insights on how to use the T approach. In the experiment, advanced clarinetists were asked to alternate practice of the exposition of a concerto and an etude excerpt every three minutes until they achieved a total of twelve minutes per piece, which resulted in four rounds. This random condition was compared to the blocked condition in which the same clarinetists were asked to practice another exposition of a concerto and another etude excerpt that were similar in difficulty but in a unique block of twelve minutes per piece. The random condition led to better scores compared to the blocked condition. It is important to notice that the players did not receive any instructions on how to practice during each of the three-minute blocks. They were free to use their time as they wished.

The same freedom of how to use the given time in each mini-block is one characteristic of the T approach. It may involve larger passages than the NR approach and it has more flexibility on what will be practiced within the selected passage during each round. For example, if the player selects the first theme of the exposition of a concerto as one of the tasks to be practiced in a mini-block of two minutes, the passage does not necessarily need to be repeated from beginning to end during those two minutes in every round. The learner may choose to practice that passage as they desire, perhaps focusing on problematic or challenging segments within the passage. On subsequent rounds, the individual does not need to practice exactly in the same way as in the first

[150] Carter and Grahn, "Optimizing Music Learning."

round. It might be more useful to focus on different parts of the passage, or perhaps one may even choose to play the entire selected passage one or two times putting everything together. In this way, the practice might feel more dynamic.

5.1.2 Applying the Number of Repetitions approach (NR)

In the NR approach, the variable is the number of repetitions instead of the amount of time. As with T, it is important to plan an appropriate number of repetitions per task in each round also following the challenge framework principles,[151] i.e., for optimal amounts of CI, the lower the nominal and/or functional difficulty of the task, the lower the number repetitions per round is needed and vice versa (see Figure 8).

Nevertheless, the choice must be wise in order not to fall towards excessive consecutive repetitions. Going beyond five or six consecutive repetitions may already be inappropriate. The "rule of three" is a great starting point here as well: three tasks, three repetitions each, three rounds. As the learner gets more experience, they may manipulate the variables in a different manner for more optimal learning. Some tasks may need more repetitions while others may need less; it will depend on the difficulty of the task and the level of the learner.

Additionally, the player does not need to be confined to the same number of repetitions in all tasks in a given round. In the same round some tasks may have five repetitions, others two, and others one for example (A-5x, B-2x, C-1x / A-5x, B-2x, C-1x / A-5x, B-2x, C-1x…). Although this is more complex to keep track and may need more experience with CI manipulation, it may be very useful since not all tasks are equally challenging.

[151] See Guadagnoli and Lee, "Challenge Point."

5.1.3 Differences between NR and T

The major difference between NR and T – besides time vs. repetitions – is the length of the segments and the way that each task may be practiced (see Table 2 for NR and T characteristics). The first is more specific on what exactly needs to be repeated, usually shorter passages or exercises, while the second will probably involve larger passages with more freedom on what to focus for each round. Nevertheless, the player needs care with the T approach as some portions inside the selected passage might be overlooked or may have fewer repetitions than necessary. Thus, at times the NR approach may be more advantageous especially for specific challenging passages with technical issues – a specific shifting, a challenging fingering, a peculiar string crossing, a certain bow stroke, etc. (see Table 2). Furthermore, differently from T, it is important for the player to repeat the selected task in its entirety in all repetitions when using NR. If the player finds another segment inside the selected task that needs extra work, the best decision may be to isolate it and turn it into a new task. However, it is possible sometimes to choose larger sections for NR as well, especially when the player intends to put small segments together into larger passages.

Table 2. Comparison between the T and NR approaches and their characteristics.

Comparison and characteristics of T and NR	
Time (T)	Number of Repetitions (NR)
Amount of time per mini-block	Amount of repetitions per mini-block
May involve larger sections	Usually involves shorter passages and segments
Allows freedom to choose precisely what needs to be repeated within a section	Very specific on exactly what needs to be repeated
In general, more useful for practicing repertoire	In general, more useful for practicing technique
Good fit for technical maintenance	Good fit for practicing specific challenging segments on repertoire
More flexible and it might feel more dynamic	Easier to keep track on what has been repeated
Might be more suited for more experienced learners	May be more accessible for novices and youngsters

For repertoire, T might be more useful in general; however, NR might be preferable when solving specific problems and for challenging segments. NR may also be very helpful for run-throughs of large sections and even entire movements. For scales and technical exercises, NR may be preferable in general, but T may be very useful for technical maintenance. T is more flexible and might feel more dynamic, while NR is easier to keep track of what has been repeated. Moreover, NR might be more accessible for novices and youngsters since they do not have enough experience with practice, and therefore it may be harder for them to decide what to prioritize. Thus, during the lesson the teacher could select and mark the segments that need more work and suggest the student to use the rule of three with the NR approach. Nevertheless, there is no right or wrong choice necessarily; players, students, and teachers need to use their experience, good sense, and their personal preferences when deciding which approach to use and when. Using both approaches on different occasions may be the best option, especially for more experienced players and students.

5.2 Systematically increasing CI levels

When deciding how much and when CI should be implemented, Edwards[152] recommends taking into consideration the skill level of the learner, age, and task complexity. As noted in the discussion in the previous chapter, novices and youngsters may generally receive more advantage from CI schedules that are closer to lower levels of the continuum, while more experienced learners may receive more advantage from

[152] Edwards, *Motor Learning and Control*, 412.

higher levels of CI. As already mentioned, task difficulty and complexity may also play a role.[153]

From this perspective, a systematic increase of CI, as recommended in the literature, is a good strategy and can be used to meet the needs of learners in their current skill level. It may also be a more natural way to manipulate CI in real world situations. Coker[154] suggests the implementation of higher levels of CI once a learner has achieved a certain degree of proficiency.[155] In general, a practice of any new skill will naturally fall towards the low CI levels in the beginning. Once the learner gets the basic understanding of the skill and is capable of producing a rough approximation of the correct mechanics of the task, higher levels of CI may already be beneficial.[156] For some tasks it will take only few attempts, while other more complex actions may need more blocks of repeated practice. In some cases, the shift to higher CI levels can be done at a quicker pace; in others, the gradual increase of CI may be necessary through incorporating various types of hybrid schedules. This might include beginning with blocked practice, then using different hybrid schedules that increase the levels of CI, and finally using a pure random schedule (see Figures 6 and 7). Moreover, as mentioned in the previous chapter, hybrid schedules may also prevent over or underestimation of the learning progress.

In practical terms, using the NR and T approach, the amounts of CI can be manipulated by increasing or decreasing the time and/or the number of repetitions in each mini-block over the practice session. The higher the amount of time or number of

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[153] Guadagnoli and Lee, "Challenge Point," 219–20.
[154] Coker, *Motor Learning and Control for Practitioners*, 274.
[155] See also Magill and Anderson, *Motor Learning and Control*, 395; Edwards, *Motor Learning and Control*, 412.
[156] Coker, *Motor Learning and Control for Practitioners*, 274.

repetitions, the lower the CI and vice-versa. If the student or teacher feels that the task is already on track towards achieving the desired result, they may reduce the number of repetitions in the next round. Systematically pushing students to a more random practice schedule may prove to be very effective. For example, when using the NR approach, one can choose to start with six repetitions in each mini-block, then four in the next round, then three, etc until one is practicing single statements only of the section. Performing a section only once actually mimics a performance situation. Nevertheless, if the teacher (or students themselves in the practice room) notices that the student is struggling considerably with the action, it may be necessary to go back to a more repetitive schedule until difficulties are overcome.[157] Yet, although it is tempting to keep repeating over and over a very challenging passage or exercise, it is important to remember that evidence suggests there is significantly less benefit to working on a passage in the traditional blocked practice method. The whole principle behind the blocked practice vs. random practice is that elevating the amounts of CI (i.e., less consecutive repetitions) enhances learning.

The present discussion about implementing different practice schedules in a violinist's daily routine does not intend to lead to the conclusion that blocked practice is not effective at all, however. Blocked practice does produce learning, but implementing random and hybrid schedules may lead to higher and faster improvements on learning with the potential of reducing frustration. It is very common for teachers to instruct students to repeat ten, even twenty consecutive times in order to "engrave" the information in the brain. These recommendations prioritize repetitions above everything

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[157] Schmidt and Lee, *Motor Learning and Performance*, 246.

else, relegating the learning process to simply a matter of repetition. Although repetition and learning do have a relationship, repeating a task twenty consecutive times may have a quite different learning outcome than if those same twenty repetitions were alternated with other tasks using either random or hybrid schedules.

Edwards considers the introduction of random practice as "both science and art"[158] and says that practitioners should be sensible to their own experience, to a learner's needs, and to rely on research when designing and recommending practice schedules to their apprentices. Although conclusions and agreements among scientists about all the aspects of the effects of contextual interference in real-world application are far from definite,[159] the key element stressed by most researchers in the motor learning field is that the traditional view of repeating exhaustively each task in blocked practice fashion should be abandoned, or at least reconsidered, especially in the later stages of learning.

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[158] Edwards, *Motor Learning and Control*, 414.
[159] See Damian Farrow and Tim Buszard, "Exploring the Applicability of the Contextual Interference Effect in Sports Practice," in *Progress in Brain Research*, vol. 234 (Elsevier, 2017), 69–83, https://doi.org/10.1016/bs.pbr.2017.07.002.

CHAPTER 6

VARIABLE PRACTICE

Along with the discussion of how random and blocked practice schedules influence the learning process when considering different tasks or different skills to be learned (multiple-task practice), there is also a deep discussion about the impact on learning when practicing variations of the same skill (single-task practice), which can be practiced in either constant or varied form. Practice variability can be defined as "the variety of movement and context characteristics the learner experiences while practicing a skill."[160] Thus, if the skill (or task) is repeated exactly in the same manner every time, with no variation, and under the same conditions and context, it is said that the skill is practiced in constant fashion. Conversely, varied practice happens when the learner decides to implement variations of the task across repetitions. In violin practice, for instance, if the individual wants to practice a D major scale in constant fashion, they will repeat it always in the same tempo, with the same bow stroke, same bowing, same fingering, and so on. If they want to implement variable practice, then these parameters will change across repetitions. Changing the context, such as playing in different venues, rooms, or for different audiences, also creates practice variability.

When talking about open or closed skills, at first it seems logical to use constant practice for closed skills and varied practice for open skills. Open skills are those where the environment is unpredictable, constantly changing, and the movements and actions are constantly adapting to each situation. Most team sports are predominantly open skills, for example. Closed skills, on the other hand, are those where the environment is

[160] Magill and Anderson, *Motor Learning and Control*, 369.

predictable, and the actions and movements are performed in the same way. Motors skills are classified in a continuum between open and closed skills.[161] Violin playing is certainly closer to the closed skill classification side of the continuum in general, but it also has elements of open skills such as sight-reading and improvisation where the unpredictability increases significantly. Chamber music also has some elements of open skills. Although the music is the same, the musicians must be constantly prepared to adapt and react to each other in order to keep a great balance and ensemble.

On the one hand, constant practice seems to be ideal for closed skills because the goal usually is to reproduce the action always in same manner. The violinist, for instance, practices the first measures of a violin concerto aiming for the execution to be very similar whenever performing it. On the other hand, open skills, such as team sports, require an inherent variability for most of their tasks because the environment and context are constantly changing. Thus, one may conclude that variable practice should be more effective for those cases. A basketball player, for example, wants to shoot the ball successfully from any part of the basketball court whether facing an adversary, whether deciding to do a dribble before the shot, or whether facing any other unpredictable situation that might occur.

However, the answers for these questions may not follow this simple logic. The general preference for constant practice is found even in open skills. The practice of the fundamentals, for example, at times follows the constant practice approach, repeating the task over and over in the same way (e.g., training soccer passes in the same manner to the same target and same distances several consecutive times with the goal of perfecting it).

[161] Schmidt and Lee, *Motor Learning and Performance*, 16.

Aside from the understanding already discussed in the previous chapters that blocked practice is questionable, the view that constant practice is more effective than variable practice is also challenged in the motor learning literature, not only for open skills, but even for closed skills.

One of the classic examples in the literature is the study by Shea and Koll in 1991.[162] Participants were divided into four different groups to perform a task in which they had to produce a specific force using a beveled grip. The force applied to the grip was measured by a force transducer apparatus. They performed twenty blocks of practice trials followed by one retention test after twenty-four hours. The Specific, or constant, group (S), performed five trials per block at the criterion force (150N) with sixteen seconds interval between trials (one hundred trials total). The Specific + Variable group (SV) performed the same five trials per block at the criterion force, but instead of resting for sixteen seconds between trials, they performed three additional trials that were 25N or 50N above or below the criterion force (100N, 125N, 175N, and 200N). This resulted in seventeen trials per block (five at the criterion force and twelve at other forces). The total of trials was 340 (one hundred trials at 150N and 240 trials at variable forces). The Specific + Specific group (SS) had the same procedure as the SV group, but the additional trials were also at the criterion force (total of 340 trials at 150N). Finally, the Specific + Alternative group (SA) filled the intervals between the criterion trials with an unrelated task. On the next day on the retention test, all participants performed one block of five trials at the criterion force (150N).

[162] Charles H. Shea and Robert M. Kohl, "Composition of Practice: Influence on the Retention of Motor Skills," *Research Quarterly for Exercise and Sport* 62, no. 2 (June 1991): 187–95, https://doi.org/10.1080/02701367.1991.10608709.

One would expect the SS group to have the best performances and learning outcomes of all groups since it was the group that practiced the most at the criterion force (340 trials at 150N). However, results at retention showed that the SV group significantly outperformed all groups. The S and SA group had similar outcomes and, surprisingly and contrary to the expectations, the SS group's performance results were weakest by far. Even having more than three times the number of trials at the criterion force, SS was outperformed by all groups, including the S group that did nothing but rested during sixteen seconds between trials. One conclusion of the study was that repetitions of the same task with almost no rest between trials (SS) may impair learning. However, and more importantly, the results of the study indicate learning was enhanced when those extra repetitions are on variations of the same task (SV group).

With the aim to replicate these results in applied settings, in 1993 Landing, Hebert and Fairweather[163] conducted an experiment using basketball set shots in a similar design as the previous study. Twenty-eight female college students with no previous experience were divided into two groups: the criterion, and the criterion + variable groups. All participants performed forty trials in each of the three days of the acquisition phase (120 trials total). While the criterion group shot all the 120 trials at the distance of twelve feet, the variable group shot their 120 trials from eight feet, twelve feet, and fifteen feet (forty trials for each distance) in random order across the three days of practice. The retention test was performed seventy-two hours after the last day of practice and all participants shot at the criterion distance (twelve feet) in two blocks of five trials. The results were

[163] Dennis K. Landin, Edward P. Hebert, and Malcolm Fairweather, "The Effects of Variable Practice on the Performance of a Basketball Skill," *Research Quarterly for Exercise and Sport* 64, no. 2 (June 1993): 232–37, https://doi.org/10.1080/02701367.1993.10608803.

very similar to those from Shea and Kohl, i.e., even shooting three times less than the criterion group at the distance of twelve feet, the variable group significantly outperformed the criterion group on retention.

Landing and his colleagues also included data about the outcome of the participant's very first attempt on the retention test. It shows an even larger difference between groups. When comparing the performance of the last block of practice with the very first attempt on retention, the variable practice group had an improvement, while the criterion group had a significant drop in performance. From a music practice perspective, this is very significant; violinists spend hours in the practice room, for example, aiming to perform at the highest level on their "first shot" when in a performance context. This experiment indicates that variable practice is more effective to achieve that goal.

A study by Douvis reproduced similar results in a study with forehand drive in tennis.[164] The criterion task was to hit a specific target on the tennis court. Some important additional features found in this study are the selection of two age groups – children (ages nine to ten) and adolescents (ages eighteen to nineteen) – and a much longer period of practice, which consisted of eighteen practice sessions over forty days. They also added a control group that was not given any specific target; their goal was simply to pass the ball over the net. As in the previous experiments, the variable group resulted in significantly better performance on the retention test. Surprisingly, the control group was no worse than the criterion group. This suggests that having only one target or

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[164] Stavros J Douvis, "Variable Practice in Learning the Forehand Drive in Tennis," *Perceptual and Motor Skills* 101, no. 2 (2005): 531–45, https://doi.org/10.2466/pms.101.2.531-545.

not having a target at all did not make a difference in learning. Results revealed similar trends regardless of age group.

A recent study conducted by Hernández-Davo and his colleagues[165] testing tennis serves, this time with experienced players, also found advantages for the variable practice, but with an important difference. In their design the target remained constant for both groups; what varied in the variable group was the technical movements in each repetition. While individuals in the constant group were asked to repeat the movements as similar as possible, subjects in the variable group were asked to modify some aspect in each repetition. Modifications were made on a) the base support – stepping on the floor, on five, or on ten centimeters thick mats; standing on one leg or both legs; b) modifying the position of the subject on the court; c) modifying the toss of the ball; d) modifying where the player was facing; and d) modifying the length of the movement. In this way every subsequent repetition was different. Results from the retention test, performed after twelve training sessions, revealed that the variable practice group was significantly more accurate than the constant group. This indicates that variable practice can be achieved not just by changing task goals (e.g., targets), but also by changing the task execution, i.e., the way that the task is performed (technical aspects).[166]

Along with the aforementioned studies, other examples of studies supporting the benefits from variable practice are also found in hurdling,[167] basketball free-throw

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[165] Hernández-Davo et al., "Variable Training."
[166] For further discussion see Rajiv Ranganathan and Karl M. Newell, "Changing Up the Routine: Intervention-Induced Variability in Motor Learning," *Exercise and Sport Sciences Reviews* 41, no. 1 (January 2013): 64–70, https://doi.org/10.1097/JES.0b013e318259beb5.
[167] Wolfgang Schöllhorn et al., "Stochastic Perturbations in Athletic Field Events Enhance Skill Acquisition," in *Motor Learning in Practice – A Constraints-Led Approach* (London: Routledge, 2010), 69–82.

shooting,[168] skating,[169] handball for experts,[170] and motor skill learning tasks with children.[171] Furthermore, an integrative review by Soderstrom and Bjork shows further benefits from variable practice even in verbal and academic learning areas. They present studies in which varying the conditions between study sessions, even only changing study spaces for example, seems to benefit long-term retention as well. [172] Schmidt et al. add that the evidence of the benefits of variable practice is "reasonably strong" with basically no indication that it impairs learning and conclude that "overall, in practical settings, it is reasonably safe to say that attempts to make the practice more variable for learners will result in greater learning and generalizability."[173] Thus, the literature generally supports the positive effects of variable practice over constant practice and suggests that it may be beneficial for both open and closed skills, motor and non-motor skills, laboratory and applied settings and for a variety of ages and skill levels.[174]

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[168] Daniel Memmert, "Long-Term Effects of Type of Practice on the Learning and Transfer of a Complex Motor Skill," *Perceptual and Motor Skills* 103, no. 3 (2006): 912–16, https://doi.org/10.2466/pms.103.3.912-916; Elizabeth L Shoenfelt et al., "Comparison of Constant and Variable Practice Conditions on Free-Throw Shooting," *Perceptual and Motor Skills* 94, no. 3 Pt 2 (2002): 1113–23, https://doi.org/10.2466/PMS.94.2.1113-1123.

[169] Geert J.P. Savelsbergh et al., "A New Method to Learn to Start in Speed Skating: A Differencial Learning Approach," *International Journal of Sport Psychology* 41, no. 4 (2010): 415–27.

[170] Juan A. García-Herrero et al., "The Load of Practice Variability Must Be Regulated in Relation with Learner Expertise," *International Journal of Sport Psychology*, no. 47 (2016): 559–70, https://doi.org/10.7352/IJSP.2016.47.559.

[171] For a review in studies with children see Jin H. Yan, Jerry R. Thomas, and Katherine T. Thomas, "Children's Age Moderates the Effect of Practice Variability: A Quantitative Review," *Research Quarterly for Exercise and Sport* 69, no. 2 (June 1998): 210–15, https://doi.org/10.1080/02701367.1998.10607686.

[172] Soderstrom and Bjork, "Learning Versus Performance," 183–85.

[173] Schmidt et al., *Motor Control and Learning*, Chap. 10.

[174] Coker, *Motor Learning and Control for Practitioners*, Chap. 10; Timothy D. Lee, Richard A. Magill, and Daniel J. Weeks, "Influence of Practice Schedule on Testing Schema Theory Predictions in Adults," *Journal of Motor Behavior* 17, no. 3 (September 1985): 283–99, https://doi.org/10.1080/00222895.1985.10735350; Schmidt et al., *Motor Control and Learning*, Chap. 10.

6.1 Theories Behind Variable Practice

There are two main theories behind the benefits of practice variability: schema theory[175] and dynamic systems theory.[176] Schmidt's schema theory is widely mentioned in the literature and is largely responsible for generating multiple investigations on variable practice.[177] It predicts that the success of future performances depends on the amounts of variability experienced during practice, especially when transferring to a novel task. Simply stated, schema theory says that this happens because when the individual experiences variability, all this information is stored in the memory which then strengthens what is called the recall schema. The more variability, the stronger the schema. This process is believed to promote generalization of the skill to a variety of situations and contexts, which then helps to transfer that knowledge to novel situations.[178] Although constant practice also develops recall schema, it does, in theory, at a much lesser extent.

Theorists from the dynamical system sustain that skill acquisition is best achieved when learners face variation of a task because it forces them to continuously find different task solutions. When learners experience a variety of movements, they are also exposed to a wider range of possible solutions for a certain action, which may have a

[175] Richard A. Schmidt, "A Schema Theory of Discrete Motor Skill Learning," *Psychological Review* 82, no. 4 (1975): 225–60, https://doi.org/10.1037/h0076770; Richard A. Schmidt, "Motor Schema Theory after 27 Years: Reflections and Implications for a New Theory," *Research Quarterly for Exercise and Sport* 74, no. 4 (December 2003): 366–75, https://doi.org/10.1080/02701367.2003.10609106.
[176] See Francisco J. Moreno and Eva. M. Ordoño, "Variability and Practice Load in Motor Learning.," *Revista Internacional de Ciencias Del Deporte* 11, no. 39 (January 1, 2015): 62–78, https://doi.org/10.5232/ricyde2015.03905.
[177] Schmidt et al., *Motor Control and Learning*, Chap. 10.
[178] See Schmidt, "A Schema Theory of Discrete Motor Skill Learning"; Schmidt, "Motor Schema Theory after 27 Years."

positive impact when attempting novel tasks.[179] Caballero and her colleagues state that variability helps the learner adapt to the ever-changing environmental and anatomic constraints imposed on them.[180] Thus, variable practice may be beneficial because it forces the learner to adapt with more frequency to different conditions, which in turn generates more flexibility. Moreover, the individual has more opportunities to explore and compare different task solutions from different contexts. In this way, the learner is provided with a "repertoire of actions" that can be selected in order to adapt to those changes.[181]

6.2 Factors that Influence the Effects of Variable Practice

Even with many studies giving wide support to the variable practice principle, there are some experiments in which the effects of variable practice were not as strong as expected.[182] However, there are important characteristics during practice that were noticed by some researchers that seem to modulate the variable practice effect.

As observed by Lee, Magill and Weeks, a key factor that seems to influence the effectiveness of induced variability is the practice schedule.[183] They argue that in the experiments in which there were dubious results, the variable group frequently practiced in a blocked practice fashion instead of random order. Thus, blocked practice seems to

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[179] See Moreno and Ordoño, "Variability and Practice Load in Motor Learning."
[180] Carla Caballero et al., "The Role of Motor Variability in Motor Control and Learning Depends on the Nature of the Task and the Individual's Capabilities," *European Journal of Human Movement* 38 (2017): 14.
[181] Ranganathan and Newell, "Changing Up the Routine," 64.
[182] For a discussion see Landin, Hebert, and Fairweather, "The Effects of Variable Practice on the Performance of a Basketball Skill"; Karl M. Newell, "Schema Theory (1975): Retrospectives and Prospectives," *Research Quarterly for Exercise and Sport* 74, no. 4 (December 2003): 383–88, https://doi.org/10.1080/02701367.2003.10609108; Jacques H.A. Van Rossum, "Schmidt's Schema Theory: The Empirical Base of the Variability of Practice Hypothesis," *Human Movement Science* 9, no. 3–5 (September 1990): 387–435, https://doi.org/10.1016/0167-9457(90)90010-B.
[183] Lee, Magill, and Weeks, "Influence of Practice Schedule on Testing Schema Theory Predictions in Adults," 284.

limit the advantages of variable practice over constant practice. Breslin and his colleagues conducted an experiment with basketball free shots, similar as the Landin and colleagues' study.[184] The results revealed no difference between groups. However, in this case the variable group practiced using blocked schedule instead of random order, which shows further evidence to the Lee and colleagues' point. In addition, Moreno and Ordoño suggest that some experiments that show no better performance for the variable practice group failed to put enough time between the practice phase and the retention/transfer phase.[185] One conclusion that may be drawn is that the advantages of variable practice may need more time to be manifested.

Another discussion is about the amounts of variability or loads of variability. As in the case of CI, nominal and functional difficulty of the task seem to interplay with the amount of variability, i.e., too little or too much variability can have null or even opposite effects depending on the task characteristics (or difficulty) and the learner's skill level.[186] According to Caballero et al., novices naturally experience more inherent variability when attempting the new skill; inducing more variability than needed may be excessive and counterproductive. Thus, there may be an optimal amount of variability that helps on the learning process.[187]

Along these same lines, Moreno and Ordoño state that the given load of variability a) may be weak and not produce anything significant in terms of learning, b)

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[184] Gavin Breslin et al., "Constant or Variable Practice: Recreating the Especial Skill Effect," *Acta Psychologica* 140, no. 2 (June 2012): 154–57, https://doi.org/10.1016/j.actpsy.2012.04.002.
[185] Moreno and Ordoño, "Variability and Practice Load in Motor Learning.," 69.
[186] See Caballero et al., "The Role of Motor Variability in Motor Control and Learning Depends on the Nature of the Task and the Individual's Capabilities."
[187] Caballero et al., 17.

may be so great that it causes overstress and can have negative effects on learning, or c) it may have optimal amounts of variability that challenges the learner at the right extent and optimizes learning.[188] In the early stages, variability is inevitably present, since the learner produces a wide variety of different movements while attempting to make the correct actions, so no extra variability is needed. However, after the learner is more familiar with the task, the literature indicates that adopting variable practice becomes more and more beneficial.[189]

Empirical evidence of the benefits derived from different practice loads is found in a study by Moreno, Peláez, Urbán, and Reina.[190] It revealed that participants performing a throwing task benefited more from intermediate levels of variability than from lower or higher levels. Furthermore, results from a study with handball conducted by Garcia-Herrero and his colleagues showed that novices had greater improvements on their overarm throwing skills when experiencing constant practice, while experts only improved their skills under variable practice.[191]

Empirically, it is very tempting to assume that variability in practice is bad for skill acquisition. One may think that to achieve the correct outcome, the skill needs to be practiced several times in the exact same manner, i.e., in a constant fashion. However, in a strict sense, a true constant practice is very challenging to achieve, not to say

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[188] Moreno and Ordoño, "Variability and Practice Load in Motor Learning.," 68.
[189] B. Ann Boyce, Cheryl A. Coker, and Linda K. Bunker, "Implications for Variability of Practice from Pedagogy and Motor Learning Perspectives: Finding a Common Ground," *Quest* 58, no. 3 (August 2006): 334, https://doi.org/10.1080/00336297.2006.10491886.
[190] Francisco J. Moreno et al., "Different Levels of Variability versus Specificity of Practice Applied to Increase the Performance under Statics Task Constraints.," in *16th Annual Congress of the European College of Sport Science: Book of Abstracts* (Liverpool, England: Research Institute for Sport and Exercise Science, 2011), 327, https://fedorabg.bg.ac.rs/fedora/get/o:6374/bdef:Content/get.
[191] García-Herrero et al., "The Load of Practice Variability Must Be Regulated in Relation with Learner Expertise."

impractical. Our limbs rarely depart from the exact same place when performing a given task. The movements are always slightly different; the force produced and the timing to do the same action have slight variations in each attempt; our bodies may feel differently depending on the day; on some days our muscles feel more responsive than others; our mental state may also vary in each practice session. Moreover, when considering the violin, modifications on weather, humidity, room temperature, as well as strings and bow hair constantly wearing out with use, have an impact on the instrument which may demand slight modifications from the player in order to produce the desired outcome. Furthermore, we are frequently playing in different rooms and halls with different acoustics. All those factors may influence the way that we play the same passage. This inevitably generates variation. Motor learning literature goes further, saying that variability is not only inevitable but may also be desirable. Research in neuroscience and motor control has demonstrated that variability "is actually necessary for motor learning and skill."[192]

Moreno and Ordoño argue that variability is important not just for generalizability (transfer) but also for adaptation, flexibility, and exploration.[193] According to their studies, as the learner progresses through the learning stages, skill becomes more stable and more resistant to perturbations. "Stability does not necessarily mean greater consistency, but more resistance. Indeed, the more stable behavior will be that with the greater adaptability."[194] In fact, violinists face many sources of perturbation that may affect performance such as stage anxiety, tension, different muscle responsiveness,

[192] Ranganathan and Newell, "Changing Up the Routine," 64.
[193] Moreno and Ordoño, "Variability and Practice Load in Motor Learning.," 71.
[194] Moreno and Ordoño, 71.

mental state, different acoustics, weather changes, strings slightly out of tune in the middle of the performance, etc. The ability to adapt to and resist these perturbations leads to higher performance and numerous studies have shown that variable practice is more effective than constant practice in achieving these results. Given the importance of variability for motor learning, violin teachers and students should consider induced variability as a practice tool. The next chapter addresses ways on how to apply variable practice to violin teaching and learning.

CHAPTER 7

VARIABLE PRACTICE APPLIED TO VIOLIN PEDAGOGY

As discussed in the previous chapter, there is significant research that suggests approaches to motor skill acquisition that overemphasize constant practice do not produce optimal results. In fact, qualities such as stability, resistance, flexibility, and adaptation are better stimulated under induced variability during practice, and they lead to better performance. Hence, having the motor learning literature as a background, this chapter provides practical guidelines and suggestions on how to apply variable practice principles to violin pedagogy.

7.1 Task Goal and Task Execution

Ranganathan and Newell, suggest that variability can be achieved through modifications on either the task goal or task execution.[195] On the former, the variations lead to different outcomes of the task. On the latter, the expected outcome is essentially the same in all variations, but the method of execution is modified as in the Hernández-Davo et al.'s study.[196] Practicing shifting between different notes is an example of task goal modification. Practicing shifting between same notes in the same string but exploring different ways to execute it, is an example of varying the task execution. Both can be very effective as demonstrated by Landin and his colleagues[197] (changing task goal in basketball free shot) and by Hernández-Davo and his colleagues[198] (changing the task execution in tennis serves).

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[195] Ranganathan and Newell, "Changing Up the Routine," 66–68.
[196] See Hernández-Davo et al., "Variable Training."
[197] Landin, Hebert, and Fairweather, "The Effects of Variable Practice on the Performance of a Basketball Skill."
[198] Hernández-Davo et al., "Variable Training."

In order to differentiate modifications on task goals from task execution in violin pedagogy, the criteria used in the present paper concerns the resulting sound: if the variation modifies the resulting sound, then it concerns task goal. For example, playing a scale in the same tempo, but using different bow strokes (e.g. *spiccato* and *detaché*), results in different sounds. If the variation maintains essentially the same results on sound, then the variation is on task execution. For example, playing a scale in the same tempo, with the same bowings, same bow stroke, but varying the fingerings, produces very similar results on sound. Table 3 shows how variation can be achieved in each category.

As seen in Table 3, the player has a wide range of possibilities to induce variability. Technical exercises, scales, and *arpeggios* may benefit greatly from it. Using task goals, the violinist may practice these using different dynamics, bowings, bow strokes, characters, tempos, etc. When using task execution as a source of variation, the individual may explore different fingerings, different bow speeds, different parts of the bow, and so on.

Another way to achieve variability is to use the same technique applied to different contexts. For example, if the student wants to practice a bow stroke, *spiccato* for instance, they can practice different passages or exercises using *spiccato*. Thus, *spiccato* becomes the task while the different passages become the variations.

Table 3. Different forms to induce variability in violin practice by modifying task goal and task execution

Task goals can be varied through:	Task execution can be varied through:
- Dynamics - Articulation - Tempo - Different target notes on shifting exercises - Mood - Rhythm - Color - Character - Style - Bow strokes - Bowings aiming for different sounds - Point of contact, bow speed, and pressure aiming for different sounds - Fingerings aiming for different sounds - Different parts of the bow aiming for different sounds	- Exploring different ways to play a given segment aiming for less effort and energy - Modifying posture, hand shape, height of the right elbow, angles of the limbs, etc. - Playing the same passage in different strings aiming for the same sound quality (e.g., playing on the E string looking for the same color sound as the A string). - Different fingerings (on scales, arpeggios, repertoire, etc) - Playing in different parts of the bow aiming for similar sounds - Different points of contact, bow speeds, and pressure aiming for similar sounds - Different bowings aiming for similar sounds - Playing in different venues, halls, and rooms - Playing for different audiences - Playing in different violins and bows - Changing the focus of attention (focusing on different aspects of the execution, parts of the instrument, musical aspects, etc.)

7.2 Variability on Repertoire and Technique

Variation on technical exercises is not a new concept in violin pedagogy; it is widely recommended by most pedagogues and teachers. In fact, many technique and scale books from violin pedagogues such as Sevcik, Dounis, Galamian, Flesch, Schradieck, Fischer, etc, suggest many variations for practicing their exercises and scales. Their recommendations resonate with the motor learning literature about the importance of variability and its potential for generalization.

Nevertheless, at times students get overwhelmed and confused about how to practice all those endless variations. The approaches most frequently used and encouraged end up being the constant and blocked practice for each variation, trying to master each of them separately before practicing the next one. The practice becomes daunting and, as already discussed, constant and blocked practice may not be the most effective. Using variable practice to schedule those variations as the motor learning literature suggests, may enhance learning and create more engagement during practicing. The NR approach may be very helpful to schedule these variations as will be discussed later.

While using variation in technical work is somewhat common in the practice routine of many musicians (though not necessarily applying it as the motor learning literature suggests), implementing practice variability on repertoire is less so. One may assume that variable practice makes sense only when working with technique, scales, and *arpeggios*, while repertoire should be practiced in a more constant fashion. However, repertoire benefits from variable practice as well. One way that musicians already apply variability in repertoire practice is incorporating different (and, in particular, slower) tempi when practicing fast passages. Nevertheless, there are countless ways to use practice variability which may be very helpful in the learning process. For example, one may play the same passage using different moods, characters, colors, dynamics, sometimes even with different articulations, which are all examples of task execution variability.

Inducing variability on task execution can also have a more exploratory character. One may use it as a tool to find more efficient ways to achieve the same results on sound, which can serve both repertoire and technique. The player may explore different forms of playing the same passage but with better posture, using less effort and energy, exploring ways to play it with more comfort, and/or exploring different fingerings and bowings.

Obviously, the player will not use all those different variations on stage and surely the intention is not to play in a different way every time when performing or even in every practice session. Variability should not get to the point of overwhelming the learner. However, practicing using a certain degree of variation as a practice tool potentially furthers the exploration of task solutions, strengthens the memory through comparison and contrast,[199] may foster adaptability, and may keep the mind more engaged as already discussed in the previous chapter.

Focus of attention may also be a source of variation for task execution. Focusing on different aspects of playing in different attempts, may be effective for the application of both variable practice and focus of attention. The player may use different distances of external foci suggested in chapter 3. When using EF1, the player may choose different aspects to focus on each repetition – the bow, the strings, the point of contact, the fingerboard, etc. The same principle can be applied to the EF2; the focus may be directed to the dynamics, the notes, the sound of the articulations, the character, etc. If the player wants to use EF3 to apply variability they may aim for different musical expressions on different attempts. One may even explore using different levels of external focus on different trials as well. An example of incorporating this would be to focus on the bow in the first attempt (EF1), on the sound image on the second attempt (EF2), on the character of the passage in the third attempt (EF3), and then repeat the round one or two more times.

Finally, variability can also be implemented by using what Boyce, Coker, and Bunker call "challenges."[200] Using challenges such as how fast, how slow, how long, and how many times, can be an effective way to produce variety and to generate motivation and attention during both lessons and practice sessions. Examples of challenges include,

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[199] See the elaboration hypothesis on section 4.2 Hypothesis behind CI
[200] Boyce, Coker, and Bunker, "Implications for Variability of Practice from Pedagogy and Motor Learning Perspectives," 322.

‘how long can you sustain this note with a consistent sound?’, ‘how fast (or how slow) can you play this scale?’, ‘how little bow can you use in this passage?’, and ‘how soft (or how loud) can you play this passage?’ Additionally, challenging students to play while doing a secondary task may also be a source of variation (e.g., playing while walking, while standing in one leg, while counting the beats, etc.). This may also help to keep students engaged, especially younger ones.

7.3 Scheduling Variable Practice

Scheduling variable practice follows a very similar approach as manipulating CI in multiple task practice (see Appendix B). The player may use the NR approach, but instead of selecting multiple tasks to practice, the player selects multiple variations of the same task. Thus, the violinist may choose a passage from the repertoire or a technical exercise and practices them in different ways. If the player wants to practice an E major *arpeggio* in tempo *moderato* using the NR approach for example, they could play it using three different bow strokes such as *detaché* (A), *spiccato* (B), and three note slurs (C). Then, the violinist could choose to repeat each variation one time in each round using serial order along four rounds (ABC/ABC/ABC/ABC). For repertoire, one could select a short passage of sixteen measures or so and play it in three different characters (A, B and C). Each character could then be repeated two times per round using serial order in three rounds (AABBCC/AABBCC/AABBCC).

Since the motor learning literature suggests that blocked practice tends to nullify the positive effects of variable practice, it is important to keep the number of the repetitions closer to higher amounts of the CI continuum, i.e., fewer consecutive repetitions. Thus, in general, it is advisable to have three or fewer consecutive repetitions.

Most studies adopt one or two consecutive repetitions in their design. However, if the task is very challenging and the learner is struggling too much to improve the performance, more consecutive repetitions may be needed (as with CI manipulation in multiple task practice).

If there is a variation that the player wants to emphasize with the intention to be the criterion variation (CRT), then the criterion may be repeated more frequently than the other variations. This can be achieved by either having more consecutive repetitions for CRT (CRT-3x, A, B, C / CRT-3x, A, B, C /…) or alternating CRT with the variations in a way that resembles a rondo form (CRT, A, CRT, B, CRT, C, CRT…). Although there are no studies exploring the impact of this last type of schedule, it may give psychological reassurance to the player as the criterion task is being reinforced. Furthermore, this may be especially helpful in repertoire practice as it reinforces the intention of the performer while in a variable practice context.

7.4 Manipulating Loads of Variability

The motor learning literature suggests that there is an optimal amount of variability for each individual. Optimal amounts may vary depending on the task and the context. Moreno and Ordoño state that "the same task design may provoke different levels of practice load for different people and even for the same learner in different situations."[201] From this perspective, if a violinist has been practicing technical routines always in the same manner for years, they might not be receiving the best learning advantages from it. Thus, it is very important for teachers, players, and students to constantly observe and test different loads using good sense and their own experience in

[201] Moreno and Ordoño, "Variability and Practice Load in Motor Learning.," 68.

order to achieve the best learning outcomes. As mentioned in the previous chapter, researchers suggest that novices may benefit more from lower levels of induced variability, while experts draw more advantages from higher levels.[202] These findings follow the same trends of CI manipulation. Boyce, Coker, and Bunker suggest that, as with CI manipulation, variability may be introduced after the learner understands the basic dynamics of the task and is able to reproduce approximations of the movement pattern.[203] This will depend on the task complexity and on the skill level of the learner (nominal and functional difficulty respectively).[204] There are tasks that are difficult for one individual, but may be easy for another person.

Novices learning more complex skills, such as how to play with the bow on the string while maintaining a good bow hold, will probably be overwhelmed if they are asked to produce variations of it, for example. It may be counterproductive to ask a beginner child to vary the point of contact while attempting to play an open A string for the first time. In this case it may be more effective not to practice variations of the task. Instead, they may benefit more from multiple task practice using a hybrid schedule. For instance, the teacher could ask the student to play on the A string with the bow four to eight times (task A), then repeat two times the "rocket exercise" (task B), then ask to play one or two times an already learned open string song using *pizzicato*, such as Stomp Song or Each and Every Ant (task C). The student then could go back and repeat the same

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[202] See Caballero et al., "The Role of Motor Variability in Motor Control and Learning Depends on the Nature of the Task and the Individual's Capabilities," 17; Coker, *Motor Learning and Control for Practitioners*, 268; Edwards, *Motor Learning and Control*, 417.
[203] Boyce, Coker, and Bunker, "Implications for Variability of Practice from Pedagogy and Motor Learning Perspectives," 334.
[204] See Guadagnoli and Lee, "Challenge Point."

sequence for two or three more rounds (ABC/ABC/ABC …). In the next lesson, the learner may be ready to benefit from small variations of task A, like playing on different strings.

When the student is ready to introduce variability on a task (which may be very quickly), the most accessible way to manipulate the loads of variability is to either increase or decrease the number of variations. More variations generate greater loads while fewer variations generate lower loads (see Figure 10). Nevertheless, one needs good sense not to select too many variations, otherwise it might overwhelm the learner.

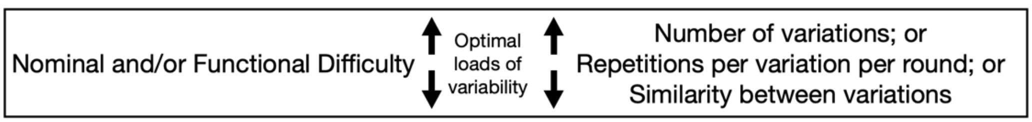

Figure 10. The relationship between nominal and/or functional task difficulty and the number of variations, or the number of repetitions per task per round, or more similar or dissimilar variations for optimal loads of variability.

Additionally, the player may regulate variable practice loads through the same method used in CI manipulation. In this case, more consecutive repetitions decrease the load, while fewer consecutive repetitions increase it. When using the NR approach, the learner can regulate the number of consecutive repetitions of each variation in each round according to their needs: the more challenging the variations for that learner the more repetitions and vice-versa. It is important to reiterate that it is even more desirable to lower the number of consecutive repetitions in variable practice than when practicing multiple tasks because schedules towards blocked practice seem to negatively impact the benefits of variable practice.

Another way to modulate the amount of variation is to balance the degree of similar vs. contrasting. For instance, for advanced students, selecting very different bow strokes such as *spiccato*, up bow *staccato*, and *legato* to practice a three-octave *arpeggio*, may provide an appropriate and beneficial challenge. However, asking this from an advanced-beginner student will certainly be overwhelming even if it is only a one-octave *arpeggio*. It may be more productive instead to ask them to use *detaché*, *martelet,* and three note slurs since they are more similar.

Variable practice may be a very effective tool to enhance long-term learning and it has a wide range of possibilities for application to violin pedagogy. Although there is a traditional strong emphasis on constant practice in music, one should consider that research suggests otherwise. Learning a skill well involves the ability to adapt the acquired knowledge or skill to new contexts and situations as well. One analogy frequently used is making a "recording" in the brain and then just "pressing play" whenever one wants to perform the action. However, performing an action is not a passive activity, it is quite active. It involves thinking, planning, and adapting to the current situation. Thus, the learning process is best when it makes the skill flexible, stable, adaptable, and resistant to perturbations.[205]

Motor learning research suggests that these qualities are better achieved when the individual is exposed to a certain degree of variation. Variability is a constant in violinists' routine. They are frequently exposed to different situations and contexts (e.g., different rooms, venues, audiences, playing solo, chamber music, orchestra, etc.) and use similar techniques in a variety of different contexts in their repertoire. Moreover, they face many types of perturbations on a daily basis such as natural variations in their bodies and minds as well as influences on their instruments caused by weather and material

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[205] Moreno and Ordoño, "Variability and Practice Load in Motor Learning.," 71.

deterioration. Therefore, the importance of induced variability may prove to be very helpful for both learning and performance enhancement.

CHAPTER 8

CONCLUSION

The process of learning how to play the violin, or any other instrument, requires deliberate practice and good instruction. Deliberate practice involves reasoning and ongoing reevaluation, search, and discovery of different practice tools. In line with this exploration, this document seeks to connect violin pedagogy with motor learning, an important area that is growing in interest among musicians. With decades of research, the motor learning literature presents scientific findings on motor skill acquisition investigating different practice tools. In the present paper, three topics from the motor learning literature are reviewed and discussed, and contain insights and guidelines for application to violin pedagogy. These topics are focus of attention, practice schedules, and variable practice, and the application and suggestions presented in this document can also be expanded and adapted to other musical areas and instruments.

As discussed throughout the paper, the learning process is dynamic with no unique rule that can be applied to all individuals in all situations. The idea that learning is related only to the number of correct repetitions one makes is not supported by scientific evidence. According to numerous motor learning studies, maximum positive learning outcomes are achieved by manipulating the way in which the tasks to be learned are arranged, the amount of variability during practice, and to what the learner is directing their attention in terms of internal or external focus. It is also evident that each practice tool needs to be manipulated differently depending on the situation and the individual. Age, level, and task difficulty influence how to use these tools. It is also important to consider the difference between learning and performance when assessing practice techniques since performance levels at times are not an accurate representation of learning. Additionally, this paper provides insights and guidelines derived from the motor learning literature as well as the author's own experiences to help violinists and musicians receive the most advantage possible out of the chosen principles.

Using external focus of attention (EF) is a simple and effective way to maximize both performance and learning outcomes. The general commonsense belief is that learning and performance are better improved when individuals direct their focus to their limbs and/or body mechanics (internal focus of attention - IF). Focusing on how to produce an action (cause) seems at first to be more logical than focusing on what the action does (effect). This reasoning is also widely present among music and violin pedagogues. However, the motor learning literature provides overwhelming evidence that directing the focus externally, i.e., to the effects, creates a more successful outcome.

Nevertheless, phrases like "think about your elbow level," "relax your wrist," or "focus on how your fingers move," are excessively present during lessons and might lead students to conclude that they need to be always directing their attention internally which may even hinder learning and performance, especially in more advanced performers. Although on some occasions it is impractical to avoid internal focus of attention, its use should be temporary, only a "zoom-in" to the problem and, as soon as the cause-effect is properly understood, zooming back out to the external foci will prove to be more efficient and effective. The use of external focus of attention is a somewhat more natural path when dealing with experts in a motor skill area. However, the motor learning literature suggests that using and directing the attention externally, even in the early stages of learning, produces better learning outcomes and has the potential of achieving automaticity sooner.

Hence it is imperative for the student and teacher to direct the external focus to farther distal points and to constantly experiment with different focal distances to get the best results possible. It is important to remember that the manipulation of the three different levels of external focus of attention classified in this paper – instrument-related aspects (EF1), desired sound or the sound image (EF2), and emotional intentions or musical expression (EF3) – should take into consideration the individual, their level, the passage, and the difficulty of the task. The more advanced the learner is, the more benefit they draw from farther focal distances. Additionally, a great advantage when using and evaluating the external focus of attention tool is that, among the three topics discussed in this paper, it is the only one that has shown a direct relationship between performance and learning, i.e., the gains in performance during acquisition usually reflect the gains on retention. This makes the assessment of this tool much easier.

When sequencing tasks to be learned, practice schedules and the contextual interference effect challenge commonly held beliefs and practices among musicians and music educators. According to the motor learning literature, isolating and exhaustively repeating each task separately (blocked practice) does not produce the best long-term learning results. In fact, it has the potential of creating an illusion of the learning progress and might become a source of frustration for both the student and the teacher. Thus, introducing contextual interference (CI) and organizing the task towards a random practice schedule is more effective on learning outcomes.

The use of hybrid schedules is a great tool to manipulate contextual interference levels and to meet the learner at their current needs. More consecutive repetitions lower the amount of CI and vice versa. Nominal and functional task difficulties interplay with the amount of CI that is needed to produce optimal learning outcomes; that is, advanced players and/or "easier" tasks may benefit from higher amounts of CI while beginners and/or "harder" tasks may benefit more from lower amounts. Manipulating contextual interference requires experience; thus, this paper suggested the "rule of three" as a simple and accessible way to start using this tool: three tasks, three repetitions, three rounds for the NR approach and three tasks, three minutes each, three rounds for the T approach. However, the most important principle is that musicians should reevaluate recommendations about repetition in given passage as the means to "engrave" it in the brain. A better option is to repeat the task the same amount of times, but alternating it with other passages or exercises.

Finally, it is generally thought that the violinist needs to repeat the tasks (a technical exercise or musical excerpt, for example) in an exact and constant fashion so that the information is stored in the brain with more fidelity, precision, and reliability. Once again, motor learning studies show evidence to the contrary. Learning a skill includes the capacity to adapt to different situations and resist to perturbations in order for the skill to become stable and flexible. The higher the capacity for adaptation, the higher the stability. Violinists face many different sources of perturbation such as stage anxiety, tension, mental state, different venues and rooms, playing for different audiences, etc. Moreover, the technical work that is done outside repertoire is aimed to be applied to the widest range of situations possible. Inducing variability exposes the learner to a wider repertoire of possibilities that can be used in different situations. Learning is optimized when it makes the skill flexible, stable, adaptable, and resistant to perturbations.

The player may induce variability through modifying the task goal (variations on the task) or task execution (modifications on how to execute the task). This document provides several suggestions for how in which a violinist may employ these concepts, like varying tempo, dynamics, bowings, rhytms, fingerings, bow strokes, and exploring different technical ways to play the same passage in their practice. Testing variability is also encouraged, not only in technical work but also when practicing repertoire, such as playing the same passage in different tempos, with different characters, dynamics, and varying articulations. It is important to schedule the variations that are going to be practiced in a manner which avoids blocked schedules as research suggests that blocked practice tends to nullify the benefits of variable practice. The "rule of three" is again a great starting point: three variations, three repetitions, three rounds.

Although the three practice tools analyzed in this paper provide concepts that go against strong beliefs in some musical circles, they have solid support from scientific findings. Unfortunately, many of those beliefs generate anxiety and frustration for both teachers and students. It is very common to hear phrases like:

"You need to be aware of every detail of your performance when playing,"

"You need to repeat exhaustively until you are sure it is stuck in your brain,"

"You are not repeating enough, that's why you are still struggling with this passage," "You must repeat every single time as equal as possible because every time you do it differently, it confuses your mind,"

"Try to practice at the same time of the day, in the same room, every day as similar as possible,"

"Today you are making silly mistakes, are you sure you practiced?"

Motor learning studies show that following these practices produces lower outcomes than CI learning. Given the compelling evidence of numerous motor learning studies, it is time that violin players and teachers change the lens on how we view the learning process. In incorporating motor learning practices, the potential for greater musical, technical, and psychological progress is limitless.

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APPENDIX A

USING PRACTICE SCHEDULES ON VIOLIN PRACTICE

1. Select the tasks (2-6 recommended): ______________________
2. Select the approach: T (Time) or NR (Number of Repetitions)
3. Choose the amount of T or NR:

    T (1-3 min recommended): ________________

    NR (1-6 recommended): __________________
4. Choose either serial or random order*
5. Choose the number of rounds (3-6 recommended**): __________

The rule of three is a great starting point:

- Using T: choose three tasks, T, three minutes, three rounds, rest for three minutes.
  Total is 30 minutes.
- Using NR: choose three tasks, NR, three repetitions, three rounds.
  There is no set amount of time.

Keep in mind:

- Use good sense.
- Be specific and deliberate on the task choices.
- Use timer for the T approach.
- Mark with pencil the selected tasks.
- Seek the optimal level of CI for you or for your student by manipulating hybrid schedules.***
- Lower functional and nominal difficulty may benefit more from higher levels of CI, i.e., tasks that are easier for a certain individual should have fewer consecutive repetitions or less time.
- Remember that immediate performance gains during practice do not necessarily reflect gains on learning.
- Remember to use the focus of attention principles.

Focus of attention principles in violin pedagogy:

- Classification:
    - IF - Bodily Mechanics
    - EF1 - Instrument Related Aspects
    - EF2 - Desired Sound and Sound Image
    - EF3 - Emotional Intentions and Musical Expression
- Test different focal points challenging yourself or your student to more distal points as you practice, always with good sense.

*Serial order is easier to keep track of, but random order adds unpredictability.

**If one wants to practice more rounds, it is recommended to have fewer consecutive repetitions.

***See figure 7.

APPENDIX B

INDUCED VARIABILITY ON VIOLIN PRACTICE

1. Select the task: ____________________
2. Select the variations* (2-6 recommended): ____________________
3. Choose the number of consecutive repetitions (1-3 recommended): ________________
4. Choose either serial or random order**
5. Choose the number of rounds (3-6 recommended***): ________

The rule of three is a great starting point:

- Three variations, three repetitions, three rounds.
- If the goal is to explore different and more efficient ways to execute the task, It may be more useful to set an amount of time for it.

Keep in mind:

- Use good sense.
- Take note of the variations.
- Choose deliberately either task goal or task execution to vary.*
- When using task execution as a way of technical exploration, the practice does not need to follow such a structured form. It is more useful to set an amount of time for it. Use timer in this case.
- Using different "distances" of focus of attention is a great way to induce variability (task execution).
- Seek the optimal loads of variability for you or for your student manipulating the number of variations, number of consecutive repetitions, or degree of similarity between variations.
- Lower functional and nominal difficulty may benefit more from higher loads of variability. In other words, variability is more beneficial for tasks that are easier for a certain individual.

*See Table 3
**Serial order is easier to keep track, but random order adds unpredictability.
***If one wants to practice more rounds, it is recommended to have fewer consecutive repetitions.

Table 3. Different forms to induce variability in violin practice by modifying task goal and task execution

Task goals can be varied through:	Task execution can be varied through:
- Dynamics - Articulation - Tempo - Different target notes on shifting exercises - Mood - Rhythm - Color - Character - Style - Bow strokes - Bowings aiming for different sounds - Point of contact, bow speed, and pressure aiming for different sounds - Fingerings aiming for different sounds - Different parts of the bow aiming for different sounds	- Exploring different ways to play a given segment aiming for less effort and energy - Modifying posture, hand shape, height of the right elbow, angles of the limbs, etc. - Playing the same passage in different strings aiming for the same sound quality (e.g., playing on the E string looking for the same color sound as the A string). - Different fingerings (on scales, arpeggios, repertoire, etc) - Playing in different parts of the bow aiming for similar sounds - Different points of contact, bow speeds, and pressure aiming for similar sounds - Different bowings aiming for similar sounds - Playing in different venues, halls, and rooms - Playing for different audiences - Playing in different violins and bows - Changing the focus of attention (focusing on different aspects of the execution, parts of the instrument, musical aspects, etc.)