

SKILL-ACQUISITION RESEARCH AND PIANO STUDY:
WHAT A CROSS-DISCIPLINARY APPROACH CAN TEACH US
ABOUT INCREASING THE USE OF MEMORY-ENHANCING TECHNIQUES

by

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Skill-Acquisition Research and Piano Study:

What a Cross-Disciplinary Approach Can Teach Us About Increasing the Use of Memory
Enhancing Techniques

Thesis directed by Professor David Korevaar

Skill-acquisition and expertise research have revealed a wealth of information about the processes students use to gain expertise in a wide variety of fields, including music. Some of the most interesting theories to come out of this field of research are psychological- and cognitive-science-based descriptions of superior expert memory. This project examines some of the most prominent of these theories and suggests ways in which piano teachers can use their findings to teach in a way that maximizes the potential for growth in the memory skills of their students.

The search for new, more effective teaching methods is never ending. This search fuels piano teachers' participation in all types of professional development activities, from pedagogy coursework to conference attendance and informal exchange of ideas with colleagues and peers. These avenues for exchange and dissemination of knowledge, while invaluable to us all, can occasionally result in a tunnel-visioned approach to music and education. What has been perhaps less common, however, is the borrowing of successful learning models and expertise acquisition tools from fields quite different from music.

In the last century or so, cognitive scientists' continued interest in skill acquisition and expertise in all fields has created a wealth of scientific literature on the nature of expertise, and the means by which it is attained. It is therefore ripe ground for investigation for keyboard pedagogues to ask: what can we learn about gaining musical expertise from the scientists who study expertise in general?

The answers to this question turn out to be far-ranging and multi-disciplinary. In this paper, I will explain some of the most important research about expertise across multiple domains. Next, I will explore some prevalent memory theories as they pertain to explaining expert performance. I will move from these multi-disciplinary examples to more music-specific research on the nature of expertise and skill acquisition. Finally, I will use these memory theories to argue that piano teachers can enhance their students' success by encouraging practice activities that specifically create the types of long-term memory chunks, schemas and templates that are described across different domains of expertise. This discussion of practice ideas will contain my own suggestions for exercises and

activities that will both expand the total volume of stored memory chunks available to the piano student, and also create the most flexible types of chunks possible, so that they may be applied in as many different contexts as possible.

Background on Skill Acquisition Research

Skill acquisition research came out of scientific curiosity about expert performance. Some of the earliest expertise research focused on the domain of chess. While Djakow, Petrowski and Rudik explored the memory of chess players back in 1927, it was not until the 1970s that American psychologists started to replicate and extend upon findings about expertise that were already documented in earlier Russian, German and Dutch sources. These earlier European studies had already demonstrated that chess experts had a demonstrably superior memory for chess positions than their less experienced counterparts. These findings were replicated by Chase and Simon (1973), but in the case of American researchers, they also compared the experts' memory for meaningful chess board arrangements to random arrangements¹. They found that chess masters and more novice players both performed poorly on recall of such boards. Clearly, the memory skill of these chess masters was not innate—if it were, their superior memories would show up in random arrangements of chessboards as well. This finding spawned many more investigations into the nature of expertise across multiple domains.

In 1967, Fitts and Posner proposed that progression from beginner to expert generally took place in three stages. In the initial cognitive stage, all information

¹ K. Anders Ericsson and Jerad H. Moxley, "Experts' Superior Memory: From Accumulation of Chunks to Building Memory Skills That Mediate Improved Performance and Learning," in *The SAGE Handbook of Applied Memory*, ed. Timothy J. Perfect and D. Stephen Lindsay (London: SAGE Publications Ltd., 2014), 3.

regarding the skill is stored in memory as a series of facts. Performance in this stage is unreliable. In the second stage, connections between related sub-skills are strengthened and errors are gradually eliminated. In the final autonomous stage, the required actions have become mostly autonomous, and only require conscious thought when something unusual happens.²

In addition to understanding the *nature* of expertise, researchers focused their attention on the *methods* that experts used to gain their expertise. Numerous researchers have collected information on how much time chess players of various skill levels have spent on various activities, whether playing chess games, studying in groups or studying alone. These studies have revealed that the time spent in solitary chess study was the most closely correlated activity to chess ratings, where grandmasters had studied in solitude thousands more hours than national and club-level players.³ Now to musicians, this may not be surprising, but remember that chess is a game played between two opponents. That the single most important factor in advancing one's chess level is not playing the game, but studying it in isolation, was surprising to say the least.

In 1993, Ericsson, Krampe and Tesch-Römer generalized this finding by introducing the concept of *deliberate practice*. "Deliberate practice is a set of structured activities that experts in the domain consider important for improving performance; it is often strenuous and can therefore only be maintained for limited

² Leonard A. Hill, "Mental Representation Mediation in Expert Golf Putting" (PhD diss., Florida State University, 2007), 6.

³ Ericsson and Moxley, "Experts' Superior Memory: From Accumulation of Chunks to Building Memory Skills That Mediate Improved Performance and Learning," 13.

amounts of time per day.”⁴ Furthermore, deliberate practice is characterized by “training on representative tasks with immediate diagnostic feedback and opportunities for reflection and gradual improvements by repetitive performance on the tasks.”⁵ The authors’ interest in deliberate practice stemmed from the same study’s conclusions about instrumental proficiency and total accumulated practice time—the authors interviewed violinists at the university level from different degree programs and with differing levels of instrumental proficiency and concluded that the level of proficiency attained was positively correlated with the total amount of practice put in up to that point in time.⁶ The importance of solitary practice is borne out in research into other domains of expertise as well. It is therefore obvious that the amount of total time spent in deliberate practice seriously impacts the type of progress that a student will make in any field, including piano study.

Beyond this simple observation of the type of activity that leads to expertise, we should also be interested in what it is that makes expert performance different from performance at a novice level. Ericsson and Smith (1991) proposed a three-step process to empirically study expert performance, which they called the expert performance approach: “The first step is to identify reproducibly superior

⁴ Andreas C. Lehmann, Hans Gruber and Reijhard Kopiez, “Expertise in Music,” in *The Cambridge Handbook of Expertise and Expert Performance*, edited by K. Anders Ericsson, Robert R. Hoffman, Aaron Kozbelt, and A. Mark Williams (Cambridge: Cambridge University Press, 2018), 536.

⁵ Ericsson and Moxley, “Experts’ Superior Memory: From Accumulation of Chunks to Building Memory Skills That Mediate Improved Performance and Learning,” 8.

⁶ Andreas C. Lehmann, Hans Gruber and Reijhard Kopiez, “Expertise in Music,” 537.

performance in the domain.”⁷ In the domain of chess, differing levels of expertise are conveniently standardized and comparable thanks to a numerical rating system.

“The rating system in chess provides an objective measure of the chess player’s skill level, which allows for very accurate predictions of which of two chess players will win a game.”⁸ With such a rating system in place, researchers are able to conduct research on chess players of quantifiably differing levels. This effectively achieves the second step of Ericsson’s expert performance approach, which is “eliciting the essence of the expert performance with the same set of standardized tasks, ideally presented in the laboratory.”⁹ The first studies to accomplish this in the domain of chess were the aforementioned memory studies, in which chess players had to memorize chess positions presented in a controlled, laboratory setting.

These studies helped bring the topic of memory to the forefront of expertise research. Superior working memory plays an important role in playing chess at a high level, too—in fact, memory skill is imperative to playing chess at a high level, and is likely developed alongside the skill of superior move planning. In order to visualize future consequences of a given move and use those envisioned consequences to inform decision-making, a chess player needs an extensive working memory.¹⁰ Various attempts have been made to theoretically explain the qualitative nature of the memory differences that separate novices and experts; we will examine these theories in more depth later on. For now, it is sufficient to observe

⁷ Ericsson and Moxley, “Experts’ Superior Memory: From Accumulation of Chunks to Building Memory Skills That Mediate Improved Performance and Learning,” 12.

⁸ Ibid., 12.

⁹ Ibid., 12.

¹⁰ Ericsson and Moxley, “Experts’ Superior Memory: From Accumulation of Chunks to Building Memory Skills That Mediate Improved Performance and Learning,” 12.

that expert memory is cultivated in two distinct ways: in domains like random-number memorization, memory-encoding skills are attained by active training. In other skills, memory skills are more a by-product of other requirements of expertise in the domain (as we have discussed in the case of chess).

Competing Theories on Memory and Expertise

The earliest studies of raw memory established two distinct types of memory that have dominated memory theory ever since: *short-term memory* (STM) and *long-term memory* (LTM). Theoretically, STM encodes information for a limited amount of time, and its contents are emptied when one's attention is diverted. Its total capacity is also quite limited. Experiments conducted by George Miller (1956) indicated that STM was capable of a digit span of only seven (plus or minus two).¹¹ In LTM, there is a much greater total capacity for information, but encoding it there takes more time, because it is not accessed directly (as STM is), but is accessed through some type of retrieval cue.¹²

It was Miller who suggested the concept of *chunks* as a means by which the basic limitations of STM are expanded upon. He considered chunks to be "accumulated items of related information that could be recalled as a unit."¹³ Expertise, then, is acquired when a person assimilates a large number of chunks in their LTM that can then be accessed by a "discrimination net," which allows differentiation between chunks. Chunks do not merely encode information as they can often be associated with actions; this way, when a chunk is perceived, an action

¹¹ K. Anders Ericsson and Walter Kintsch, "Long-Term Working Memory," *Psychological Review* Vol. 102, no. 2 (1995): 212.

¹² *Ibid.*, 212.

¹³ Hill, "Mental Representation Mediation in Expert Golf Putting," 10.

can be undertaken. This seems to explain much of the rapid decision making that experts do and often refer to as “intuition.”¹⁴ Chunking theory also postulates that accumulating these many chunks in LTM (somewhere between 10,000 and 100,000) takes somewhere around ten years of study.¹⁵

After these initial findings, a slew of incrementally progressive studies refining memory models came out. While the whole trajectory of this theoretical evolution is beyond the scope of this paper, let us consider a few of the problems that arose with this early memory model.

One obvious flaw is that in a wide range of highly complex tasks, people frequently demonstrate cognitive processes that surely necessitate more new pieces of information stored in STM than possible under the chunking theory. Also, it appears that experts routinely retain information that should be stored in STM for much longer than the chunking theory can explain. As a result of these flaws, newer memory models have had to be adopted.

In knowledge-based theory, expert memory is accounted for by “high-level, conceptual knowledge.”¹⁶ These concepts impact the way experts are able to relate pieces of information to one another. Experts know *more* about their domain than others, but they also understand relationships differently, organizing information in a more hierarchical fashion.¹⁷

¹⁴ Fernand Gobet, “Expert memory: a comparison of four theories,” *Cognition*, Volume 62, Issue 2 (May 1998): 118.

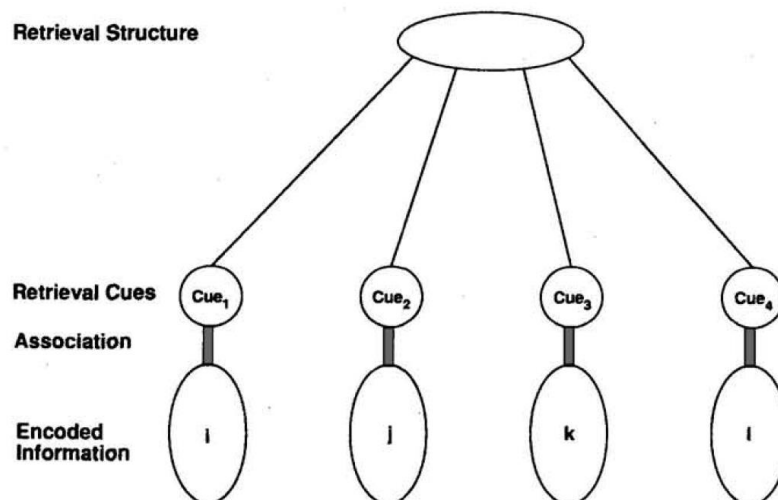
¹⁵ Ibid.

¹⁶ Ibid., 119.

¹⁷ Ibid.

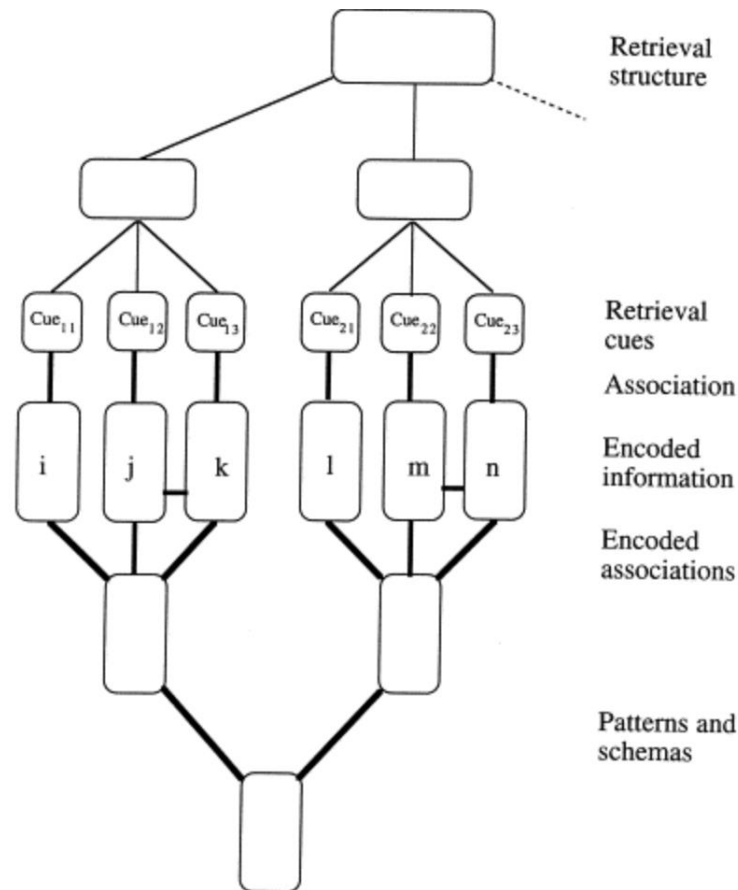
Other theories include Chase and Ericsson’s skilled memory theory, which explains expert memory as a process of encoding information into various cues and then developing “retrieval cues” to retrieve the information without having to search excessively for it. While this seems like a fairly complicated process, it is a process that gets faster with practice. A classic example would be mnemonists who create images that represent different numbers or sequences of numbers, and then place these images within a “mental map” of a real physical space (which acts as the retrieval structure). In this case, the images serve as retrieval cues and they conjure associations that trigger the encoded information (the numbers or number sequences to be memorized). These retrieval cues allow larger amounts of information to be stored temporarily in STM until they are needed, at which time they can then be conjured. For a representation, see Figure 1.

Figure 1: Ericsson and Kintsch LTWM Model (from LTWM by Ericsson and Kintsch pg. 216)



Skilled memory theory has, in turn, been elaborated upon by Ericsson and Kintsch to form a new theory, referred to as long-term working memory theory. The basic tenets are the same as in skilled memory theory. The main difference is that the memory relationships are no longer viewed as a top-down relationship from the retrieval structure, to cues, associations and finally encoded information. The connections of memory in long-term working memory theory are viewed as connecting from retrieval cues down to encoded information, and down to accumulated knowledge in long-term memory, stored in schemas and patterns. This chain of connections can also operate in the opposite direction, from patterns and schemas, up through encoded associations and up the chain to encoded information. Below is a figure illustrating this framework as well.

Figure 2: Memory Representation from Long Term Working Memory Theory (Ericsson and Kintsch 221).



The other most prevalent memory theory is Gobet and Simon's template theory. The template theory is very similar to the theory of long-term working memory in that they describe the same memory advantage used by experts, in which a portion of the long-term memory is used as working memory. Template theory differs in that templates are more flexible vessels of information than schemas. Templates are essentially schemas that can be filled with differing types of information, including chunks. A template can be thought of as being like the schematics for a house; the house can contain any number of different types of

things. While the differentiation between templates and schemas is marginal, I will henceforth use the term *chunks* to represent the smallest accumulations of related information, *schemas* to represent a higher level of pattern-forming based on hierarchical relationships and conceptual knowledge, and *templates* to represent the most flexible types of patterns, in which the information encoded by the template can be highly diverse in nature.

What is remarkable about these different learning theories is that their descriptions of experts' utilization of long-term memory in situations where novices would rely on short-term memory is actually *visible* in fMRI scans. PET and fMRI scans of experts show that when working on memory-related tasks in their field of expertise, their brains light up in regions associated with long term memory, which the researchers suggest is "compatible with functional brain re-organization."¹⁸ What is also interesting is that the transition from novice to expert can be seen with imaging as well: The brains of novices undergoing training programs light up in neither the region associated with working memory, nor the region associated with long-term memory. To explain this, Guida et. al. have suggested that the decreased activation in working memory for the novices in training is the beginning of the reorganization observed in its completed form in the brains of the experts.¹⁹

¹⁸ Alessandro Guida, Fernand Gobet, Hubert Tardieu, and Serge Nicolas, "How Chunks, Long Term Working Memory, and Templates Offer a Cognitive Explanation for Neuro-Imaging Data on Expertise Acquisition: A Two-Stage Framework," *Brain and Cognition* Volume 79, Issue 3 (August 2012), 221.

¹⁹ Ibid.

Sight-Reading Studies and Implications for Memory Training

As noted earlier, chess has been a preferred area of expertise research because of several factors, including its quantifiability and its potential for mathematical and computer-based study. Within the domain of music, sight-reading presents some similar advantages. While high level artistic performances of prepared music are hard to compare in a mere quantitative sense, sight-reading performances can be broken down into much more manageable components that measure success, such as pitch accuracy, rhythmic accuracy, and rhythmic continuity. This lends the study of sight-reading performance a uniquely objective quality. This bias in the research can also be viewed rather optimistically when one considers that “over repeated play-throughs with expert pianists performances on the first and subsequent play-throughs indicated that better sight-readers learned the piece more quickly than less skilled sight-readers.”²⁰ Indeed, sight-reading skill may be related to overall speed in learning music (although there are certainly many examples of pianists who learn quickly in spite of limited sight-reading abilities). Even if it is not, what student does not want skills that allow them to learn pieces more quickly? In this way, we can see an improvement in sight-reading as an improvement to at least the initial stage of learning a new piece of repertoire.

Sight-reading as a skill actually represents the combination of several skills. As Lehmann and McArthur note, “from a psychological viewpoint, sight-reading involves perception (decoding note patterns), kinesthetics (executing motor

²⁰ Andreas C. Lehmann and Victoria McArthur, “Sight-reading,” in *The Science and Psychology of Music Performance: Creative Strategies for Teaching and Learning*, ed. Richard Parncutt and Gary McPherson (Oxford University Press USA, 2002), 141.

programs), memory (recognizing patterns), and problem-solving skills (improvising and guessing).”²¹ It is the complex interaction of these various skills that create skill in sight-reading. Differences in sight-reading ability “can be explained through differences in the amount of relevant experience and the size of the knowledge base (e.g., repertoire).”²² It is this last point that is of utmost interest; the observation that the “size of the knowledge base” directly influences the ability to sight-read fluently suggests that by widening the scope of the repertoire of our students, we can perhaps prime them for success in sight-reading, and maybe even prepared performance.

Given the previously discussed role of memory in the development of any expertise, this point about repertoire should hardly be surprising. Still, the idea of working directly on memorizing patterns and chunks of information as a means to improving sight-reading is revealing, and it does have experimental precedent. Pamela Pike designed one such experiment involving chunking and class piano student sight-reading. She divided the students into three groups, each of which targeted sight-reading in practice over the course of six class sessions. The control group was allowed to practice without specific exercises, while the second group was given rhythmic chunking drills alongside the sight-reading examples, and the third group was given pitch-chunking drills (see Figures 3 and 4).

²¹ Ibid., 135

²² Ibid.

Figure 3: Pike's Rhythmic Chunking Drills for a Given Sight-Reading Example

The first system of music is in 2/4 time, marked *mf*. The right hand has a triplet of eighth notes (G4, A4, B4) followed by a quarter note (C5), then a quarter note (B4), and a quarter note (A4). The left hand has a quarter note (G3), a quarter note (F3), a quarter note (E3), and a quarter note (D3). Handwritten annotations include a '3' above the triplet and '1-2-3+' below the first three notes of the right hand. Fingerings '5 3 1' and '5 2 1' are written below the first and second measures respectively.

The second system of music is in 2/4 time. The right hand has a quarter note (G4), a quarter note (A4), a quarter note (B4), and a quarter note (C5). The left hand has a quarter note (G3), a quarter note (F3), a quarter note (E3), and a quarter note (D3). A handwritten annotation 'f-2-3+' is written below the first three notes of the right hand. A circle is drawn around the first measure of the right hand.

Rhythm Drill #1

Unit 11

The first staff (labeled 1a) is in 3/4 time. The right hand has a quarter note (G4), a quarter note (A4), and a quarter note (B4). The left hand has a quarter note (G3), a quarter note (F3), and a quarter note (E3). Handwritten annotations '1 & 2 & 3 &' are written below the notes. A circle is drawn around the second and third measures of the right hand.

The second staff (labeled 1b) is in 3/4 time. The right hand has a quarter note (G4), a quarter note (A4), and a quarter note (B4). The left hand has a quarter note (G3), a quarter note (F3), and a quarter note (E3). Handwritten annotations '& 2 & 3 &' are written below the notes.

The third staff (labeled 1c) is in 3/4 time. The right hand has a quarter note (G4), a quarter note (A4), and a quarter note (B4). The left hand has a quarter note (G3), a quarter note (F3), and a quarter note (E3).

The fourth staff (labeled 1d) is in 3/4 time. The right hand has a quarter note (G4), a quarter note (A4), and a quarter note (B4). The left hand has a quarter note (G3), a quarter note (F3), and a quarter note (E3).

Figure 4: Pike's Pitch-Chunking Drills for a Given Sight-Reading Example

The figure displays two musical staves for piano, illustrating pitch-chunking drills. Both staves are in the key of F# (one sharp) and 2/4 time. The first staff is marked *mf* (mezzo-forte) and features a triplet of eighth notes in the first measure, indicated by a '3' above the staff. The treble clef part consists of half notes and quarter notes, with slurs over the first two measures and the last two measures. The bass clef part consists of quarter notes. Fingerings are indicated below the bass line: 5, 3, 1, 5, 2, 1. The second staff is marked *f* (forte) and features a quintuplet of eighth notes in the first measure, indicated by a '5' above the staff. The treble clef part consists of half notes and quarter notes, with a slur over the first three measures. The bass clef part consists of quarter notes.

1a

1b

1c

1d

try to see main "melody" notes from 1b+1c - just fill in other d'

As you can see (Figure 3), the rhythmic exercises involved tapping drills. These tapping drills progressed from just the right hand tapping the rhythmic pattern of the melody in the first two measures (1a), to a two-handed tapping exercise in which the right hand tapped its opening rhythmic pattern against left-hand quarter notes (1b), to a version that included the other two rhythmic chunks of the melody against straight quarter notes (1c), and finally, to an exercise in which the hands tapped the rhythms of the entire excerpt, minus the final tied note (1d).

The pitch-chunking exercises (Figure 4) revolved around identifying and blocking the main harmonies of the left hand (1a), and then creating a skeletal outline of the melody's chord tones (1b), and combining these two into a simplified two-handed version of the piece (1c). Finally, this skeletal version is expanded into the actual version of the piece (1d), but with the main melody notes circled so that the students see which notes are from their skeleton version (1b and 1c) and which notes are merely passing tones between the others.

When the study concluded, all three groups had improved their sight-reading scores (based on the criteria of rhythmic accuracy, pitch accuracy and continuity); however, only the group that worked specifically on pitch-chunking improved in all three areas of reading.²³

The results of this study were interesting in that the pitch-chunking group did not significantly outpace the other groups in pitch accuracy improvement, and likewise the rhythmic-chunking group did not significantly outpace the other groups in their rhythmic or continuity improvements. However, the author suggested that the pitch-chunking group may have improved in all three criteria because "they recognized and were able to perform the pitch patterns, freeing up space in working memory to process and execute rhythm during sight-reading."²⁴ While the results could not prove that this was the case, the students reported experiencing significant benefit from both types of chunking exercises in self-assessments completed after the final sight-reading evaluations. Pike concluded that her study

²³ Pamela D. Pike and Rebecca Carter, "Employing Cognitive Chunking Techniques to Enhance Sight-reading Performance of Undergraduate Group Piano Students" *International Journal of Music Education*, Volume 28, Issue 3 (2010), 231.

²⁴ *Ibid.*, 243.

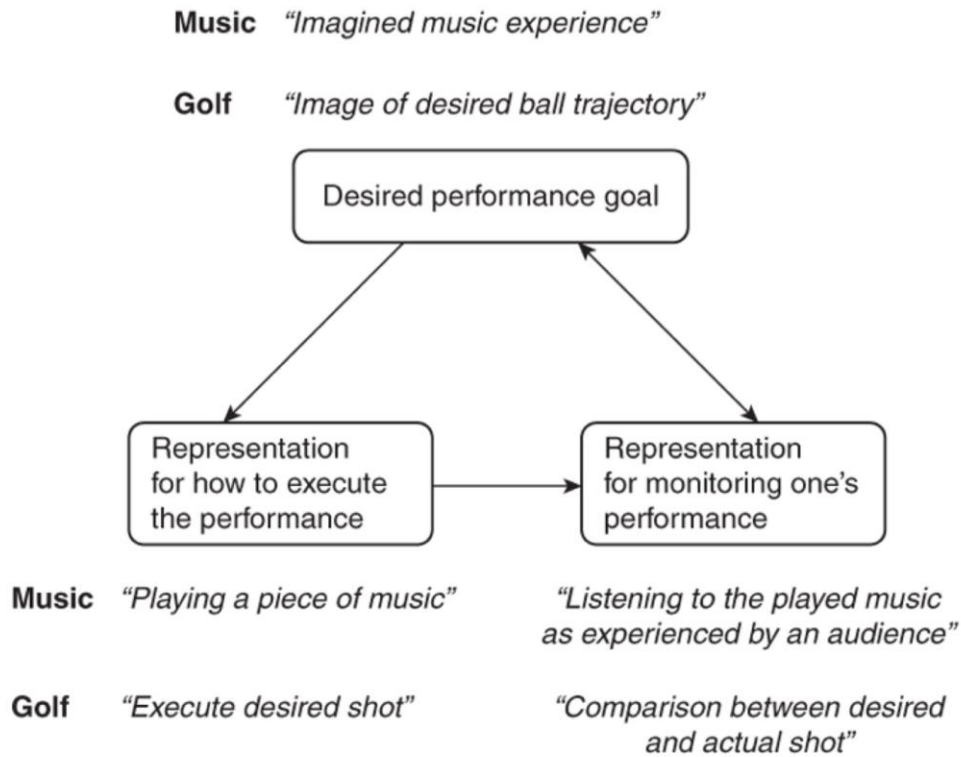
had reinforced the notion that visual cues must be linked to automated motor skills in order for sight-reading to be efficient, in confirmation of the findings of Lehmann and McArthur (2002).²⁵ While the sample size was small, and so more research into this topic is clearly needed to draw firm conclusions, these findings are themselves revealing for what they suggest about the role of memory and chunking in sight-reading: developing chunking skills is clearly helpful, but is most effective when associated chunks are wedded to easily accomplished motor programs.

Sight-Reading Recommendation #1: Beyond *Prima Vista*

Research into golf practice provides another interesting take-home on the topic of sight-reading. While music and golf are different domains of expertise, they do share certain commonalities. In particular, both involve a triangular relationship between desired performance, execution of that performance, and a critical assessment of outcome (see Figure 5). Put another way, the trajectory between visualizing an optimal performance and executing it to that level has everything to do with the strength of your self-assessment.

²⁵ Ibid.

Figure 5: Imagined performance, execution and self-monitoring in music and golf
(SAGE chapter, pg. 411)



To be more specific on the acquisition of golf skills, I would highlight Ericsson's observance of advancement in the sub-skill of putting. He points out that simply putting the shots that come up in a match setting will only improve a golfer's short-game to a limited extent. If a golfer really wants to see improvement, he must specifically work on putting as an isolated skill. Beyond the putting green, a golfer should practice the same putt more than one time, striving for more accuracy in their result each time. In this way, a golfer can learn how to read all of the variables important in judging a putt better than by only encountering each different putt one time.

To me, this suggests something powerful about sight-reading practice. We commonly tell our students to sight-read often, prioritizing continuity and the “big picture” to improve their sight-reading skills. To these suggestions, I would add that reading a piece of any difficulty only once is not nearly as helpful as taking a second or third read-through. This way, you can actually internalize something of the style you are reading and store it in your long-term memory for future use, which will hopefully increase your processing speed and fluency in recognizing similar music you read in the future.

Specific Proposals:

Teaching Methods that Could Improve LTWM and Templates

Now that we have established long-term memory, and specifically the creation of chunks, schemas and templates, as critically important in creating musical expertise, let us consider musical definitions for these types of memory structures. Musically speaking, *chunks* to refer to small motor programs that do not require advanced conceptual knowledge to aid in their execution; *schemas* will refer to more advanced patterns that do require conceptual knowledge in order to be internalized (e.g. scales, which require theoretical and technical information in order to be recognized and executed); finally, *templates* will refer to those extensions of established patterns that allow for the creation of multiple new patterns unified under the resemblance to an established *schema* (e.g. the broad category of “arpeggiation accompaniment with passing tones,” in which the arpeggiations and progressions they follow are established *schemas*, and the

broader understanding of the *variety* with which non-harmonic-tones, arpeggiation figures and progressions can be combined create a more flexible *template*).

In addition to working with students to improve their performance and artistry on each individual piece they study, we can also prioritize learning in a way that enhances these memory skills and thus, future pattern recognition. . Teaching in a way that creates these memory skills is possible throughout a student's development at the piano. Accordingly, my suggestions will include different levels of piano students, and my specific exercises will be targeted at several different experience levels, from beginners to intermediate and advanced students. Possible methods for such improvement include:

- 1) the memorization of music;
- 2) exercises that force students to anticipate or guess where a composer might take a passage next;
- 3) improvisation based on a composer's given materials;
- 4) comparing fingering choices step by step to those choices made by an expert pianist/editor;
- 5) sight-reading music and then immediately comparing one's own sight-reading to the recorded performance of the same music by an expert pianist.

First and foremost on this list is the memorization of music. While not universally accepted as a worthwhile pursuit, the practice is generally standard in the piano world since its beginnings with Franz Liszt and Clara Schumann. The fact is that no other practice likely provides such a good way of improving one's long-term memory structures. The understanding of whole-scale structure templates

(e.g., sonata form, binary/ternary forms, variations, rondo forms, etc.) as well as the local analytical processes necessitated by memorizing whole works (e.g., chord types/voicings, scalar collections, sequential treatments, etc.) provide the student who memorizes with invaluable training in memory skills that will directly translate to further ease in the styles they study.

Other than memorizing, teachers must design methods and exercises that allow their students to internalize elements of specific styles. This way, they are not limited to understanding the most obvious examples of given schemas, like an unremarkable presentation of a scale or arpeggio. In addition to the basic structures, students should be taught the vocabulary and syntax of the specific styles they study. One way to achieve this result would be to present students with incomplete passages of music, which they would be expected to complete in a manner befitting the surrounding style. Say, for example, the student is studying a Bach Minuet. You might present them with several incomplete excerpts from other pieces in the Notebook for Anna Magdalena, and challenge them to complete the passage in a way that fits the style.

Figure 6: Completing incomplete passages using anticipation and improvisation (Bach Menuet I, from “3 Minuets” from the Klavierbuchlein für W.F. Bach).



One of the most important ways in which we convert perceived patterns in music into physical action at the keyboard is by the fingerings we use. Scale and arpeggio fingerings are two examples of ready-made schemas that connect musical patterns to physical actions. But patterns in music are almost always more complex than “clear-cut” scale or arpeggio fingerings. So how, then, can we embed more flexible fingering templates in the memories of our students other than by simply re-fingering the pieces they bring to us in lessons?

One idea would be to mimic the time-honored tradition in chess of studying old games. “The chess players could simulate playing against the world-class players by trying to select each move and after selecting the move compare their move with the one that the world-class player had selected. Getting immediate feedback about one’s move immediately after making the move was predicted to be far more effective than playing a whole chess game and then figuring out if and where one could have made better chess moves.”²⁶ This fits with the criteria established earlier, in our definition of deliberate practice, which stated that immediate feedback was key to the process of improvement characteristic of deliberate practice.

So how could one recreate this approach in studying piano fingering? You could send a student with a fingering assignment, say, to finger the exposition of a sonata. The sonata itself could be broken down into sections, and the student could be instructed to check their chosen fingerings against a famous pianist’s edition of the work after fingering each section. This could do wonders to teach the student

²⁶ Ericsson and Moxley, “Experts’ Superior Memory: From Accumulation of Chunks to Building Memory Skills That Mediate Improved Performance and Learning,” 13.

the differences between fingerings generated based off of a literal application of strict fingering rules and one based off of intellectual or pattern grouping. So for example, you might have your student create their own fingering for the following excerpt:

Figure 7: Excerpt from Schumann Quintet in E-flat Major, Op. 44, Movement 1.



In this example, the student is confronted with two conflicting fingering rules. Under conventional fingering practices, the right-hand octave leaps would be taken between fingers one and five. Choosing this fingering, however, would mean breaking the rule of never putting the thumb on a black key. Conversely, if a student prioritizes avoiding the thumb on a black key, then they are left with several octave leaps between fingers two and five, which may also be seen as unsatisfactory.

Finally, prioritizing a one to five fingering of the octave leaps also does not fit as neatly with the underlying harmony; the dominant portions of each measure (in this case E-flat Major) would be broken into two separate positions as opposed to one position in the two to five fingering for the octave leaps. These different issues could lead to an invaluable discussion between teacher and student about which fingerings present the *least* amount of problems in a given passage, and when it might be important to follow patterns that are more mentally convenient than rule-

abiding. In the case of this Schumann example, the superiority of the two to five octave leaps, which allow each measure to be executed in only two positions, becomes especially apparent when you show the student the two-handed version that comes later (See figure 8).

Figure 8: Two-Handed Version of the Previous Schumann Excerpt



In this case, the avoidance of thumb on a black-key would result in a dizzyingly complex difference of groupings between the hands. By assigning only these passages as fingering exercises, you can teach your student to store one example of a fingering of “mental convenience” in their long-term memory, with the hope that other examples of this type will be more recognizable in the future because of it.

Whatever fingerings the student learns from the comparison process are only a part of the lesson gained. As Ericsson noted in the aforementioned analysis of the advantages of studying old chess games, “This type of training in selecting moves will force the player to plan ahead and search for the move and thus strain their memory skills for accurately storing chess positions in the expert’s working memory (LTWM).”²⁷ Similarly, the process of going through fingering each section and having to weigh options against one another in the decision tree of finding the

²⁷ Ericsson and Moxley, “Experts’ Superior Memory: From Accumulation of Chunks to Building Memory Skills That Mediate Improved Performance and Learning,” 13.

right fingering will force the student to remember larger chunks of the music at once. Even comparing their fingering against an editor's after completion will force the student to hold large portions of the music in their memory and scan for differences, thereby straining, and subsequently strengthening the memory over time.

Another possible way to give a student immediate expert feedback in their home practice would be to alternate sight-reading a piece with listening to an expert performance of that piece and then sight-playing the piece for a second time. This has the added effect of aurally correcting for any mistakes in their initial read-through once they hear the accurate recording from the expert pianist. Furthermore, this process will help the student to imbue the music with artistic qualities earlier in their learning process as they imitate the fully actualized performance they hear in the recording.

Another problem with the way we typically teach schemas/templates to our students is that we are most thorough with the most rare schemas/templates. Most students are made to practice five-finger patterns, scales, arpeggios and chords in all possible keys, yet these are the rudiments from which the great composers create their more interesting textures and progressions. Therefore it is highly advantageous to have students understand certain passagework *in pieces* as a template in all the various keys, since these types of passages are more common than clear-cut examples of scales, arpeggios, etc. This is not to say that the study of the basic patterns is not necessary—the mastery of the basic patterns provides the essential schemas upon which the repertoire examples expand. By first

understanding scales, arpeggios, etc., students can examine the complex ways in which these patterns are combined and altered in real passages, and can then create more fluid *templates* based on these excerpts. This can easily be achieved by assigning the transposition of a difficult passage into various keys outside the context of the piece itself.

This concept of template creation can be taken one step further. While transposition broadens the template's existence in the memory to all the various keys, it is still only one schema, in each key. But if you instruct the student in various ways to *alter* the passage in question, the template broadens significantly, and now represents multiple templates (which can be filled with *different* information) available in long-term memory. This concept was first suggested to me by my harpsichord teacher, Robert Hill, within the context of composing numerous variations of figuration on a given etude. Let us consider an example. The following is a passage from Duvernoy's Etude No. 1.

Figure 9: Duvernoy *School of Mechanism*, Etude No. 4. Varying figuration to expand template versatility and automate more motor patterns

The image displays two musical staves. The top staff is a grand staff with a treble clef and a common time signature (C). It contains a melodic line with eighth and sixteenth notes. The bottom staff is also a grand staff with a bass clef and a common time signature (C). It contains a bass line with eighth and sixteenth notes. Both staves show a passage of music with varying figuration, including sixteenth-note patterns marked with a '6' above or below the notes.

Cues and Recall

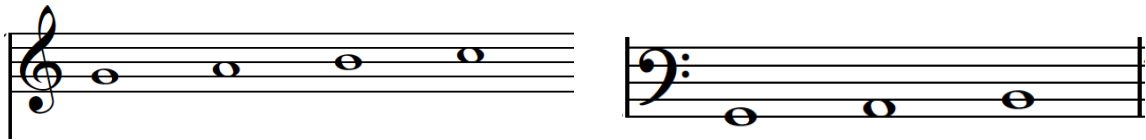
We have thus far limited our discussion of practical applications of memory theories/expertise research to techniques that seek to create a larger number of templates in long-term memory, as well as templates that are more applicable and flexible to the demands of playing real music. Let us now remember that in the previously discussed theories of memory, long-term memory templates are accessed by cues. In the case of piano playing, the cues bring up specific motor patterns that respond to the musical demands of a passage almost instantaneously. In the case of sight-reading, those cues are visual (notes/patterns on the page), while in the case of prepared performance they are either a mix of visual cues and contextual memory (playing prepared music from a score) or entirely contextual memory (playing a piece from memory). In any case, we as pedagogues should be attuned to creating as effective of cue retrieval systems as possible in our students, especially in the case of sight-reading.

To do this, we must prioritize direct connections between visually processed information on the score and kinetic responses in the body. One common problem with music reading, especially at the earlier stages, is that students require too many steps in their processing of the material. They will often read one note, and then identify the interval between that note and the next note, and proceed through the music one interval at a time, with no eye for contour or larger patterns between the notes.

One way to combat this is to teach more advanced templates for reading earlier on in the learning process. To do this, I have developed a system of

flashcards that drill individual contour shapes. I stress with the students that straight-line shapes, for example, should not be read one note at a time. Instead, the student should identify the starting point, and play however many notes they see, proceeding in the direction up or down the staff indicated by the direction of the notes. Initial straight-line type flashcards may look something like this:

Figure 10: Flashcards with Straight-Line Shapes



This technique has proven effective in establishing a more instantaneous kinetic response to a visual cue. From this point, I will often combine straight line shapes that ascend and descend to create what I call “wave shapes.” At this stage, I’ll also include repeated notes.

Figure 11: Flashcards with wave shapes, and wave shapes with repeats



The next logical step in this progression would be to combine shapes in increasingly complex ways. You can use straight lines plus repeated notes to create “rocking patterns” and you can drill doing two-hand combinations of straight-line and wave shapes. Obviously, larger intervals need to be brought into the fold at some point. No

matter what method you choose to proceed by, you are creating a set of “shape” based templates that are immediately tied to technical responses.

Indeed, this type of technical template can be drilled in other ways for more advanced students. Say, for example, you want to work with a student on rotation exercises. While some teachers, might not even call all of the following examples forms of rotation, I use the term here loosely to connote the transfer of weight from one side of the hand to the other; others might prefer the term “lateral alignment” in this case. In order to increase the total volume of rotation patterns the student has encountered, the teacher might stick to rotation examples from within the repertoire instead of using mere technical exercises. You could group together pieces from different composers that all necessitate different uses of rotational technical demands. Such a set of excerpts could look something like this:

Figure 12: Excerpts to teach different types of rotation

Bach C Minor Prelude, WTC, Bk. I



Beethoven Sonata for Piano and Violin in A Minor, Op. 23, *Allegro Molto*

In these two cases, we see two different types of rotation, the Bach example dealing in transfer of weight primarily between fingers 5, 2, and 1, while the Beethoven deals with strictly rocking motion from the outside to the inside of the hand. For a left-hand example, you could give your student a Chopin accompaniment pattern and challenge them to play it in various keys and progressions (See Figure 13).

Figure 13: A Different type of rotation quite common in the left hand (Chopin *Fantasia-Impromptu*)

Allegro agitato.

Taken as a collection, these rotation excerpts offer several advantages. Firstly, they represent mental templates from actual music as opposed to sterile, unmusical exercises. Secondly, they allow for differing types of rotation in all three examples, and the left-hand example in particular represents a more “left-hand specialized”

type of rotation through the hand that is very common in much Romantic-era writing. Finally, as excerpts of real music, this collection serves to broaden the total amount of repertoire that the student is familiar with (which, as we noted earlier, benefits their sight-reading in the long run) at the same time that it demands more understanding and careful study than would a repetitive Hanon exercise.

When you have a student study excerpts in this way, you increase the total volume of real repertoire the student is exposed to without the full time-commitment of studying each piece in its entirety. When the student encounters other examples of this type of rotation-based playing in the repertoire, they will better remember the technical mechanism by which to realize it, without having to compare it to some dry exercise and wonder if the technique applies or not.

These exercises are all designed, in various ways to accomplish the same goals. They strengthen the total amount of different repertoire and styles that a student sees; they deepen the internalization of those different styles by creating memory chunks, schemas and templates that typify elements of the different styles; they also create a wider variety of motor patterns accessible in long-term memory; and finally, they create more stable retrieval cues for the musical information stored in long-term memory.

Conclusion

When it comes to teaching keyboard instruments, many ideas are not new, they are simply repackaged. Most of the specific teaching suggestions I have made in this paper have been suggested before. But with progress comes understanding, and with the understanding provided by expertise and skill-acquisition research, along

with developments in memory theories, we can understand the *why* and *how* of effective teaching strategies. By internalizing the implications of this body of research, we can improve our self-monitoring of our own teaching practices, and take strides towards becoming expert teachers as well as expert performers. It is especially important to critically evaluate one's effectiveness in this way, based on the most current research available, because as numerous studies have shown, not all professionals produce reliably improved results based on experience alone.²⁸

²⁸ Ericsson and Moxley, "Experts' Superior Memory: From Accumulation of Chunks to Building Memory Skills That Mediate Improved Performance and Learning," 410.

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