Training thought and action for virtuoso performance

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Abstract

The skills needed to play fast, challenging music with passion and conviction are much the same as the skills needed to play reliably from memory. We illustrate the relationship between virtuosic performance and memorization by describing how an experienced cellist (the first author) prepared the Prelude from J.S. Bach's Suite No. 6 (BWV 1012) for solo cello for public performance in more than 30 hours of practice, and then taught a student pianist to memorize by showing her how to practice in a similar fashion. The cellist's practice was guided by her artistic image of how the piece should sound, which directed her attention during practice to important musical transitions. These transitions were the location of *performance cues (PCs),* thoughts about musical intentions and technical choices that the cellist reported attending to during performance. These PCs served as retrieval cues, providing places where the cellist could recover from a memory failure, making it possible for her to perform from memory. They also affected expressive timing, reminding the cellist to "breathe" between phrases, with the result that tempo arches were taller and more tilted in phrases that started with a PC than in phrases that did not. Thus, attending to musical goals during practice made it possible to play from memory and with passion and conviction.

Keywords: performance, memory, attention, practice, expression, virtuosity, performance cues

Training thoughts and actions for virtuoso performance

One of the pleasures of witnessing a virtuoso performance is the feeling of awe aroused by feats that seem beyond normal human capacities. In the 1830's, such feats were a regular feature of performances by Clara Wieck (better known as Clara Schumann) and Franz Liszt who created a sensation in the salons and concert halls of northern Europe with dazzling displays that combined technical facility and expressivity in ways that still shape performance practice today (Kopiez, Wolf, & Platz, 2017). One thing that impressed audiences at the Leipzig Gewandhaus when the 13-year old Wieck played there in July of 1832, besides her youth, was that she played without a score (May, 1912, p.78).[i] The association of virtuosity and playing from memory is no coincidence. As we will see, the skills needed to play reliably from memory are much the same as those needed to play fast, challenging music with passion and conviction.

Nineteenth-century audiences reacted to the growing fashion for virtuosic performances from memory with an ambivalence that persists to this day (Ginsborg, 2018; Hennion, 2012; Kopiez et al., 2017; Waddell & Williamon, 2017; Williamon, 1999). On the one hand, such performances are an impressive display of prowess, both physical and mental, thorough preparation, and self-assurance. On the other hand, the same qualities can be viewed more negatively as "mere virtuosity" (Ginsborg, 2018). The extensive practice required to reliably perform fast, technically challenging music from memory seems incompatible with the spontaneity and creativity normally associated with expressive performance. "The bliss of the sequences of breath taking virtuosity… [produce] their effect when they seem to arise from a moment. If they hint at too much sweat, if they seem too prepared, and if they give the impression of having been heard a hundred times, they rapidly lose their charm, dwindling to nothing short of pointless exercises" (Hennion, 2012, p. 127-128). How do performers deliver a convincingly expressive performance after putting in the long hours needed to master and memorize a musically challenging work?

To find out, we observed an experienced performer (the first author) learning a fast, challenging, i.e., virtuosic, work for a series of public performances. We have described the cellist's learning of the Prelude from J.S. Bach's Suite No. 6 (BWV 1012) for solo cello elsewhere, examining memorization (Chaffin, Lisboa, Logan, & Begosh, 2010), practice (Lisboa, Chaffin, & Logan, 2011), spontaneity (Demos, Lisboa, & Chaffin, 2016), and expression (Demos, Lisboa, Logan, Begosh & Chaffin, 2018). Here, we revisit the study to illuminate the relationship between memorization, expression, and technique. We also revisit a second study in which the cellist used what she had learned from the Prelude study to teach a piano student how to memorize (Lisboa, Chaffin, & Demos, 2015). Although the data that we discuss have been reported before, here we explore their implications for virtuosity for the first time, providing new examples and a reanalysis of the cellist's written recall.[ii]

The Prelude is an appropriate choice for our purpose because Suite No. 6 is the most complex of Bach's cello suites and a noted virtuoso piece in the cello repertoire. Its lyrical, free form structure displays the mellow sound qualities of the instrument while presenting contemporary cellists with multiple technical and musical challenges. It was written for the *viola pomposa*, an instrument with an additional E string above the four strings of the modern cello and requires rapid changes in left-hand positions that must be smoothly executed to maintain the lyrical qualities of the music. Several passages make use of the highest registers of the modern cello, for example, the high G's an octave and a fifth above middle C in bars 73 and 74. In the

words of Winold (2007), "the combination of extended range with fast virtuoso writing … makes it one of the most challenging in the cello repertoire" (p.32).

Five characteristics of the cellist's practice illuminate the connection between technique, expression, and memorization. First, practice must be guided by the big musical picture of how the piece should sound, what the noted pianist and pedagogue Heinrich Neuhaus called the "artistic image" (Neuhaus, 1958/1973, p. 17). Second, practice must be directed toward specific goals and guided by ongoing evaluation of progress (Ericsson, Krampe, & Tesch-Römer, 1993). Third, to play technically challenging music, actions must be automatic. To play automatically, and with passion and conviction, performers must practice the thoughts and feelings they want to convey to the audience along with the actions that produce the musical sounds (Demos et al., 2016). We refer to these thoughts and feelings as "*performance cues*" (PCs; Chaffin & Imreh, 2002). Fourth, PCs help the performer to play expressively by focussing attention on the musical ideas and feelings to be communicated to the audience, reducing the danger that the highly practiced performance will sound mechanical. Fifth, PCs provide a safety net that allows recovery when things go wrong, for example, if memory fails (Chaffin & Imreh, 2002; (Chaffin, Imreh & Crawford, 2002, p. 199). Thus, PCs make it possible to play challenging music both expressively and from memory.

Using PCs, however, involves thinking about highly practiced motor skills, which normally disrupts performance of the skill, a phenomenon known in some fields as "choking" (Beilock & Carr, 2001; Christensen, Sutton, & McIlwain, 2016). This suggests that use of PCs might be beyond the capabilities of many musicians. We explored this possibility by trying to teach the use of PCs to a music student of average accomplishment and motivation (Lisboa, Chaffin & Demos, 2015). The student's success suggests that a better understanding of virtuosity may lead to improvements in music pedagogy of benefit to musicians of all levels of ability and training.

Learning the music

The Prelude from J.S. Bach's Suite No. 6 for solo cello is notated in 104 bars in 12/8 time and takes about five minutes to perform (see Chaffin et al., 2010, for the score). I (the first author) video-recorded almost all of my practice and performances of the Prelude from my first sight-reading through the score until the 10th public performance, for a total of 75 practice sessions, 38¼ hours, and 3½ years. Since I refrained from mental practice as much as possible, the log that I kept of the date and time of each session and performance includes all of my time with the Prelude, with only minor exceptions. As I practiced, I talked to the camera intermittently about what I was doing, providing a record of my thinking about the piece. Finally, 10 months after the 8th public performance, I wrote out the score from memory. We transcribed my comments to the camera and the locations of starts and stops during practice and measured tempo, half-bar to half-bar, for every performance from memory that I recorded up to the 8th public performance, for a total of 28 performances, 21 in practice and 7 in public; we also scored the written recall for accuracy (Chaffin et al., 2010; Demos et al., 2016, 2017; Lisboa et al., 2011). Table 1 provides a timeline showing the long breaks, during which I did not play the piece, and stages describing the changing goals of my practice.

Table 1. *Timeline for the Prelude study showing the stages of learning, the duration of each stage, the practice sessions, amount of practice and performances in each stage, and the breaks during which the piece was not played.*

Stages	Duration in weeks	Practice sessions	Practice duration (hrs:min)	Performances
Exploration	11	1–14	8:27	
Smoothing out	4	15–23	5:19	1–5
	34	BREAK		
	5	24–27	0:50	
Listening	2	28–32	2:43	6–9
Re-work technique	1	33	0:30	
	15	BREAK		
	1	34–37	2:35	10–12
Prepare performance	3	38–47	2:07	13–14
Public performances	15	48–66	11:06	15–28
	85	BREAK		
Re-learn	3	67–75	4:37	

To capture my understanding of the music, I also provided reports of the musical structure and my PCs, marking them on separate copies of the score, the musical structure during the 2nd break and PCs seven months later, at the start of the 3rd break. For musical structure, I marked sections and sub-sections (which we refer to as "phrases"). For PCs, I marked the thoughts and feelings that I attended to during performance (Chaffin & Imreh, 2002). I reported PCs for expression or interpretation at the start of almost half of the 44 phrases. I also reported other types of PCs at places where intonation and bowing might affect the musical flow, and where I might need to attend to technical issues of fingering, hand position, and changing strings (Chaffin et al., 2010).

After I finished the Prelude study, one of my piano students decided that she wanted to learn how to memorize. Maria had previously avoided deliberate memorization. She had occasionally memorized pieces incidentally, as an unintended by-product of learning to play them, but after a few weeks the ability to play without the score would be gone. Now, she was preparing to go to university and wanted to memorize a piece to play for friends and family in the years to come. To help her memorize, I taught her to think about the music as she played by asking her to mark her thoughts about the music on a fresh copy of the score each week. We have previously described evidence that this simple exercise, combined with practice, was sufficient to turn these musical thoughts into PCs (Lisboa et al., 2015). Here, we summarize the earlier report, describing how I tested Maria's memory by unexpectedly asking her to play the piece from memory after the long summer vacation. She struggled to get through it, stopping repeatedly, but recovered by starting again at places where she had marked musical thoughts weeks earlier. We conclude that marking her thoughts created memory retrieval cues (PCs) that allowed her to restart when memory failed.

Characteristics of effective practice

The big picture. One problem in learning a challenging piece is losing sight of the artistic image of the piece during the long weeks and months of practice needed to master the

technical challenges. Part of the solution is to set the music aside and not work on it for a while, returning to it fresh and with renewed enthusiasm (Chaffin et al., 2002, p. 114). I knew the Prelude was going to be challenging and allowed time for breaks. Table 1 shows that after the initial learning I took an eight-month break, and then another three-month break before preparing for the first public performance. The breaks allowed me to hear the music afresh, rekindling my enthusiasm and refurbishing my artistic image each time I went back to it as well as providing the opportunity to strengthen my memory through relearning (Chaffin et al., 2002, p. 106; Pashler, Rohrer, Cepeda & Carpenter, 2007).

Another part of the solution is to have the artistic image (i.e., the big picture) constantly in mind (Neuhaus, 1958/1973, p. 17; Chaffin, Imreh, Lemieux, & Chen, 2003, Lisboa et al., 2011). Experts in any field are able to work productively towards a solution, even when the solution is not known. This is because experts understand the issues involved; they have the big picture. In contrast, novices are less effective; they rush in and get lost in the details (Glaser & Chi, 1988). My big picture for the Prelude included the harmonic progressions and melodic patterns that shape the three-quaver groupings running through the piece in a smooth, mellow, unbroken stream.

I knew what I wanted but getting there was not straightforward. In my head, I could hear what the piece should sound like and how I wanted it to be performed. This artistic image came from musical knowledge acquired through years of formal training in music as well as long experience in performing Bach and other Baroque repertoire and hearing others play -- performers, teachers, and students (see also Bangert, Fabian, Schubert & Yeadon, 2014). The problem was to make the appropriate technical decisions (e.g. bowings, fingerings) that would deliver the sound that I wanted.

Different editions of the score offered different solutions (Lisboa et al., 2011). I went back and forth between them, evaluating their suggestions and trying out different ways of combining the best in each. I did not finally settle on my technical choices until I began to prepare for the first public performance almost a year later. Even then, my commitment was to my artistic image of the sound more than to the particular technical tool chosen. If performance conditions called for a different solution on stage, then I could switch to whatever bowing or fingering worked best at that moment. Since I had practiced various combinations of them, I could be flexible. This intimate interplay between technique and artistic image may be responsible for the combination of spontaneity, technical agility, and expressivity often associated with virtuosity (Ginsborg, 2018; Hennion, 2012). For the Prelude, this took months of work. By the time I performed in public for the first time, I had practiced for more than 22 hours over a period of 18 months.

Figure 1 shows the first practice session. The practice record reads from bottom to top, with horizontal lines representing practice segments, i.e., the uninterrupted playing of the half-bars indicated on the horizontal axis. Each time playing stopped and restarted, a new practice segment begins on the next line up. At the bottom of the figure is my initial sight-reading through the entire piece in which I made my preliminary choice of fingerings and bowings. My playing was interrupted repeatedly by pitch mistakes, typical of sight-reading complex music. I pushed on to get a sense of the whole piece. After this initial sight reading, I returned to a particularly problematic passage, in half-bars 46–54, saying to the camera, “I am going to try a different fingering,” and then started work at the beginning of the piece.

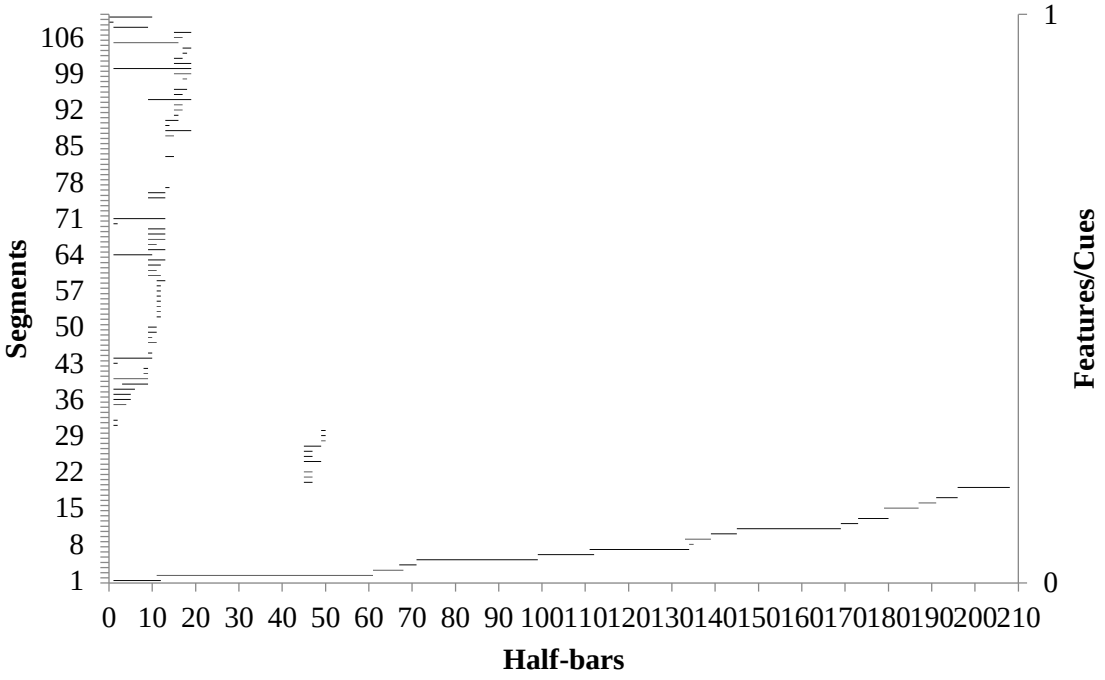

Figure 1. Practice record for Session 1 showing where playing started and stopped. (Adapted with permission from Lisboa, T., Chaffin, R., & Logan, T. (2011). A self-study of learning the Prelude from Bach's Suite No. 6 for cello solo: Comparing words and actions. In A. Cervino, M. Lettberg, C. Laws, & T. Lisboa (Eds.), *Practice of practising* (pp. 9–31). Leuven, Belgium: Orpheus Research Centre in Music).

For the rest of the session, and in the weeks that followed, I worked through the piece section-by-section. In Table 1, this stage is labeled "exploration" because my goal was to explore the different musical ideas, identify technical challenges, and find solutions. Next, I smoothed out the connections between the sections to create a unified performance (Smoothing out). Then, I listened to my playing, thinking about how the phrasing and harmonies would project in the concert hall (Listening). This led to some changes of fingering and bowing (Re-work technique), by which time the first public performance was only a few weeks away (Prepare performance). This was when I finally committed to my musical vision for the piece, which I continued to work on in practice as I performed the Prelude in a series of eight recitals over a period of seven months (Public performances). Eighteen months later, I relearned the piece for another public performance (Re-learn).

My practice was directed by my musical image, even as I made the initial decisions about technique. This is evident in the way that my practice was organized by the musical structure (Chaffin et al. 2010). Figure 2 shows Sessions 1–16, when I explored the piece by working through it section-by-section from beginning to end. I did this once, in Sessions 1–10, and then again, more briefly, in Sessions 11–14. Then, I smoothed out the connections between the sections in Session 15, and smoothed them out again, more rapidly, in Session 16. The section-by-section organization of this practice shows that I was thinking about the harmonic transitions that provide the musical shape of the piece. Attention to the musical big picture was also evident in some of my comments to the camera, e.g., "From D he goes to A which is the dominant, then the dominant of the dominant" and "crescendo … because he is repeating the A major" (Session

5). Comments of this sort, about musical structure, were about 10% of the total (Lisboa et al., 2011, Figure 2). As in other studies of experienced musicians, my practice was shaped by my artistic image of how the music should sound, even at this early stage (Chaffin et al., 2003; Chaffin, 2007).

Mostly, however, I talked about technique. Comments about technique were almost twice as frequent as any other category and made up almost half of my comments (Lisboa et al., 2011, Figure 2). Although I talked about fingering and bowing, what I was working on was realizing my artistic image (Vallacher & Wegner, 1987). As I explained to the camera, "I've got an option of fingering on bars 23 onwards to about bar 32, so I'm going to try a different fingering" (Session 1). "I'm looking at two different editions to check bowing to try and decide what to use. . . . I'm going to follow the fingering from one edition, the bowing from the other one. . . . One edition is more technically comfortable than the other, but I'm not sure if it works musically…. "Okay, there's no way out. I have to decide musically what I want and then I can choose a fingering" (Session 3). The relationship between expressive goals and technical choices is reciprocal and ongoing. Expression depends on instrumental technique, especially when the music is technically complex. Technique, in turn, serves expressive goals. This is the interplay between artistic image and technique that is central to the elusive concept of virtuosity (Ginsborg, 2018; Hennion, 2012).

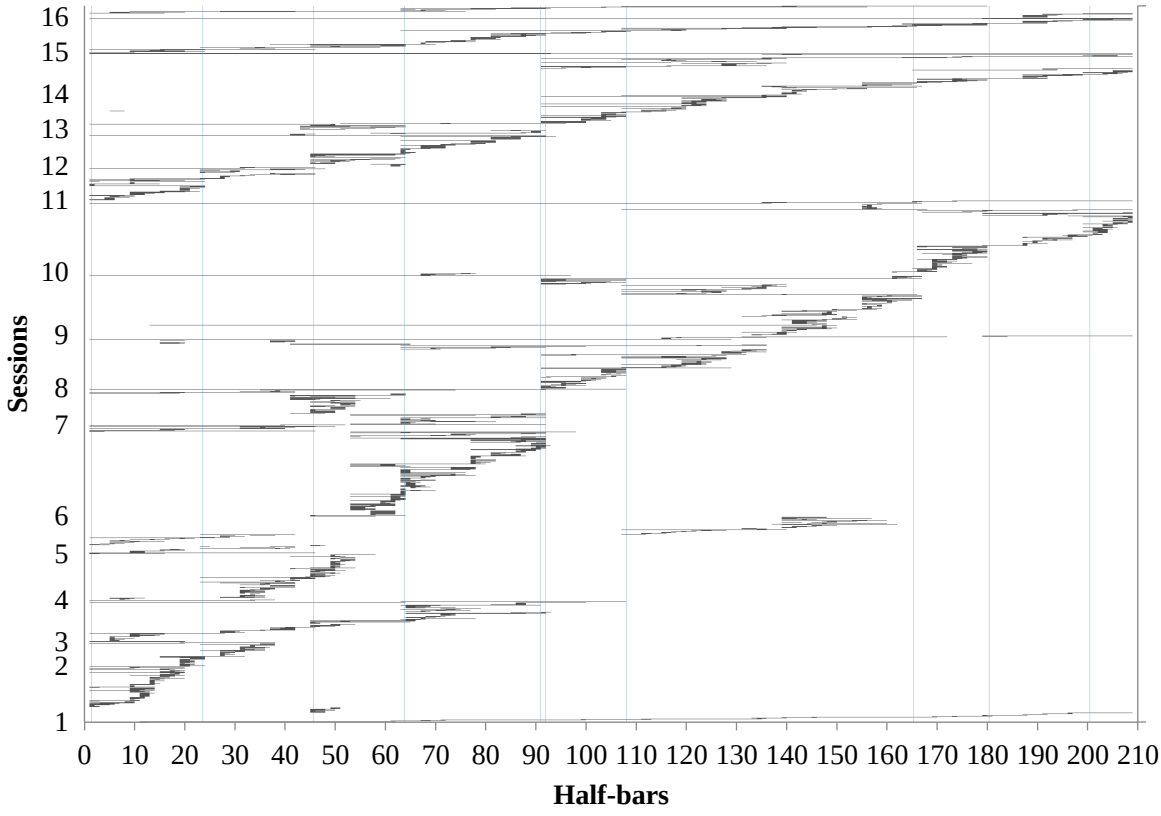

Figure 2. Practice record for Sessions 1–16 showing section-by-section practice in Sessions 1–14 and integrative practice in Session 15 and 16, and the use of section boundaries where Expressive PCs were later reported (vertical lines) as starting places.

Deliberate practice. Effective practice is not simply a matter of going through the motions. The repeated exercise of a skill, even for professional purposes, does not necessarily lead to improvement (Ericsson et al., 1993). Improvement requires setting attainable goals, developing strategies to reach them, and monitoring success. This requires concentration. That is why, as in other studies of expert practice, my practice sessions for the Prelude averaged about half an hour, ranging from five minutes to 1½ hours, depending on my schedule and how long I could maintain full attention (Chaffin et al., 2002, p. 99; Ericsson et al., 1993). On days when my energy flagged, I stopped sooner. This is reflected in my comments to the camera: "[I] need to stop" (Session 11). "Again, [I] have to think clearly" (Session 13). "I'm going to take a rest and play it again" (Session 32). "I need to have much more energy to do this" (Session 35). "My concentration is already gone" (Session 54).

Some of my more immediate goals are reflected in comments to the camera during practice, e.g., "I have to clean up this" (Session 34). I often mentioned technical challenges, e.g., "[I] changed the bow again; it's difficult to do smoothly" (Session 16), and memorization e.g., "[I'm] trying to memorize the fingering" (Session 1) and "That's where I got mixed up in my last concert" (Session 57). I talked about practice strategies, e.g., "I'm going to do rhythmic variations" (Session 1), and "I'll do it slowly to think about intonation" (Session 19) and evaluated their success, e.g., "It's been too long practicing too slowly" (Session 38), and my playing, e.g., "I tend to rush so" (Session 10), both negatively "Uh, a mess, again" (Session 18), and positively, e.g., "Intonation is really good" (Session 32). Such comments indicate deliberate practice: setting goals, choosing strategies, and evaluating their effects.

The larger goal of realizing my artistic image was not so clearly reflected in my comments but, as we saw in Figure 2, was evident in how I practiced. Figure 3 provides a closer look at the session in which I played through the entire piece from memory for the first time. At the start of Session 15, I announced, "I'm not going to focus on memorization. I'm going to play slowly and concentrate on projection of sound and getting the bow to speak clearly, and to work on left hand. It will be boring musically". Figure 3 shows that I worked through the piece systematically, starting and stopping at boundaries between sections and phrases, where I later reported Expressive and Interpretive PCs. When I reached the end, I said, "I'm going to keep the music here but see if I can remember most of it, but if I can't I'll just look" and played through the piece from start to finish without interruption. When I reached the end, I said "Ok, I just about know it. I think it's memorized". This first performance appears in Figure 3 as a horizontal line across the top of the figure, representing my uninterrupted playing of the piece from start to finish. Below it is my preparation for the performance. My practice was organized by the melodic and harmonic transitions that formed my artistic image of the music.

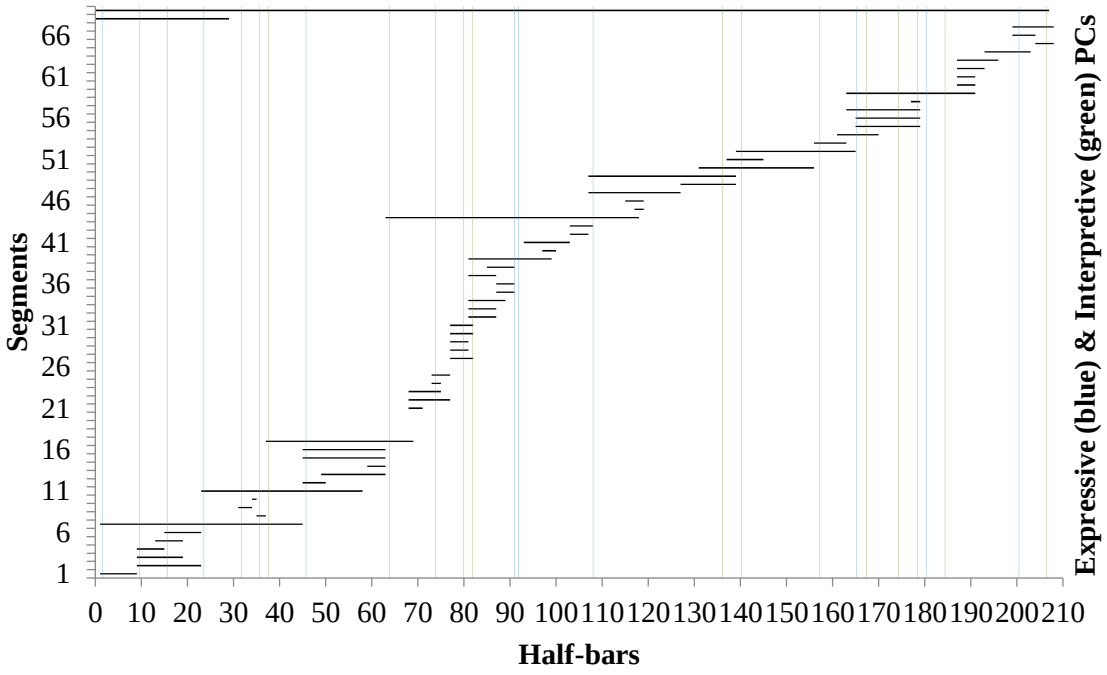

Figure 3. Practice record for Session 15 showing alternation of section-by-section work with longer integrative runs. Vertical lines represent section and phrase boundaries where PCs were later reported (blue and green respectively). (Adapted with permission from Chaffin, R., Lisboa, T., Logan, T., & Begosh, K. T. (2010). Preparing for memorized cello performance: The role of performance cues. *Psychology of Music, 38*, 3–30).

The organization of the practice in Figure 3 is another indication of its deliberate nature. Like that of other experienced musicians, my practice alternated between *section-by-section work* on short segments and *integrative runs*, putting the short segments together (Chaffin et al.,, 2002, pp. 116–118; Mikleszewski, 1989; Williamon, Valentine & Valentine, 2002). Work focused narrowly on specific problems; runs evaluated its success and re-connected the passage to its musical context. Alternating between details and the big picture in this way allowed me to do the detailed work needed to improve without losing sight of the big musical picture. As we will see below, my student practiced very differently (see Figure 8), playing through the piece without doing the work needed to perform reliably from memory without interruption.

In addition to the alternation within sessions, I also alternated between working on details versus the big picture across sessions. Figure 2 shows that, after reading through the piece in Session 1 (integration), I worked section-by-section, without playing the entire piece again, until the end of Session 14. Then, in Sessions 15 and 16, I integrated the sections into the practice performances that ended each session by working through the entire piece in sections, from beginning to end. This alternation continued with section-by-section practice in Sessions 17–20, 28–30, 33–35, and 38–44 and integrative practice in Sessions 21–27, 31–32, 36–37, 45–47 and subsequent sessions (Chaffin et al., 2010, Table 2). Thus, section-by-section work alternated with integrative practice both within and across sessions. This multi-level temporal organization of my practice kept my artistic image in focus during the long months needed to master the piece.

Automaticity and performance cues. Performers are faced with a dilemma. Their performances must be automatic to cope with the adrenaline rush of being on stage in front of an audience. At the same time, mindlessly relying on automatic motor sequences makes it hard to give an emotionally convincing performance (Hennion, 2012) or to recover from mistakes when things go wrong (Chaffin et al., 2002, p. 199). The solution is to interweave thought and action by practicing them together, turning thoughts into PCs (Chaffin & Imreh, 2002). Then, musical intentions come to mind automatically along with the actions that create the musical sounds. As I play, my thoughts are directed towards the upcoming passage, getting ready technically and musically for the transition into the next musical idea. The upcoming passage comes to mind automatically, allowing me to anticipate what to do next at the same time that I listen to what I am currently playing. It is these thoughts about each passage that I tried to indicate in my PC reports for the Prelude.

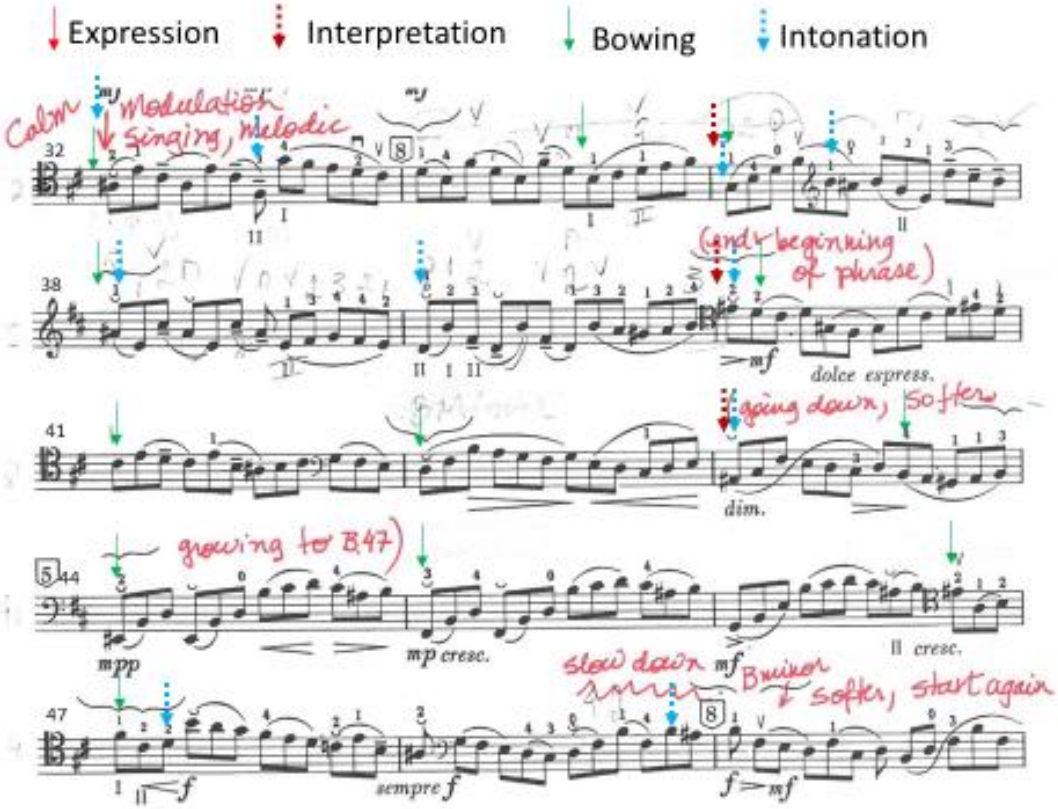

Figure 4. Excerpt from report of Expressive and Interpretative PCs for the Prelude, also showing PCs for intonation and bowing.

The day after the 8th public performance, I made copies of the score which I marked with arrows to indicate where I had thought about expression, interpretation, and four aspects of technique (bowing, fingering, hand position, and intonation) during the previous day's performance. Figure 4 shows part of my report of PCs for expression and interpretation which I annotated with verbal descriptions. (The figure also includes my PCs for bowing and intonation which I originally marked on additional, separate copies of the score). The PCs for expression and interpretation reflect my artistic image for the Prelude, articulating musical ideas that are

normally left unspoken and remain largely ineffable (Schooler & Melcher, 1995). For expression, I marked PCs at harmonic transitions, annotating them: “calm, modulation, singing, melodic”, and “slow down, B minor, softer, start again”. For interpretation, I marked PCs at melodic transitions, annotating them (in parentheses): “end and beginning of phrase”, and “going down, softer, growing to [bar] 47”. As I played, these musical intentions sprang spontaneously to mind and I listened for the corresponding qualities in the musical sound.

Often, thinking about what you are doing in this way disrupts highly practiced skills (Beilock & Carr, 2001; Christensen et al., 2016). PCs are a way of avoiding this problem. Repeatedly thinking about the musical goal for each passage during practice links the thought to the action (Chaffin & Imreh, 2002; Chaffin, 2007; Ginsborg & Chaffin, 2011). Figures 2 and 3 show that I did this in my early practice sessions for the Prelude. Intersections of horizontal lines (representing playing) with vertical lines (representing PCs for interpretation and/or expression) indicate that I started and stopped at places where I later reported PCs. The starts and stops show that I was paying attention to these musical transitions. We infer that repeatedly paying attention, in this way, created the PCs that I later reported. So, my artistic image for the music guided the creation of my PCs from the start, long before I could play fluently or up to tempo, almost two years before I reported my thoughts during the 8th public performance. I continued to pay attention, starting, stopping, and repeating these same locations in almost every practice session (Chaffin et al., 2010, Table 3). In the process, my musical intentions became interwoven with the actions of my performance, creating expressive and interpretive PCs like those in Figure 4.

Figure 4 also includes PCs for bowing and intonation, showing how PCs reflect the intimate relationship between technique and expression. Initially, I thought of my bowing decisions primarily in terms of the ‘up’ or ‘down’ direction of the bowing movement and of intonation in terms of the position of my left hand, which is responsible for intonation. For example, it was important to remember the bowing at the start of bar 32 because the pattern changed from that used in the previous passage to an alternating pattern between arpeggiated, chordal passages, with two notes per bow stroke, and more scale-like passages with three (or more) notes per stroke, as indicated by the slur marks in the score. I wanted to think about the position of my left hand because the A# at the start of bar 32 (and bar 38) is a very expressive note that I wanted to lean on to bring out its mellow qualities.

As my playing became more fluent, I thought increasingly about the expressive qualities of the sound and the singing, melodic flow of the passage, and less about bow direction and hand position. As the hand positions and intonation became more automatic and natural I was increasingly able to enjoy the expressive qualities of the intonation and the intervals. Eventually, I was able to hear the passage as whole and enjoy the way the melody unfolded across the entirety of the long phrase. At this point, bowing and intonation had become tools for musical expression; technique had become expression.

Once my thoughts and actions were interwoven, my thoughts acted as PCs, providing landmarks that I used to check my progress through the piece and ensure that the performance proceeded according to plan. As I played, my mind was mostly on the musical sound and my PCs for expression and interpretation. My actions were mostly automatic, directed by this mental map of the flow of melody and harmony. When necessary, I could zoom in on details of execution, especially where I had a PC set up. For example, in Figure 4, midway through bar 33, the PC for bowing reflects my decision to play the upward scale into the next phrase in a single bow stroke. I made this decision after extensive exploration of the alternatives. Faint traces of these explorations are still visible as erased pencil notations on my score (see Figure 4). At a

location like this, I might sometimes use the alternative bowing, switching to it spontaneously if my sound during a particular performance seemed to call for it. On such occasions, I am fleetingly aware of the substitution and the need to return to my standard bowing pattern later in the musical passage.

Expression and Performance Cues. From the perspective of the musician on stage, the role of PCs is to guide the performance, ensuring that it unfolds in accordance with the artist's image of how it should sound (Chaffin et al., 2003; Neuhaus, 1973, p. 17). I did not often mention expression in my comments to the camera during practice, but in the practice sessions following the 4th public performance I did talk about making my phrasing clearer to the audiences:

"Although I think I played more expressively [in the 4th public performance] …I didn't feel I was 'breathing' enough …. It just went from beginning to end, not stopping anywhere. So, I'll try refining those places" (Session 54).

"[I will] work slowly, thinking mainly [about] 'breathing' with every single phrase, making it very clear that it is a phrase" (Session 55).

Performers often use tempo arches to communicate their musical interpretation, drawing listeners' attention to musical transitions and phrasing by slowing down at beginnings and ends of phrases and sections and speeding up in between, a phenomenon known as "expressive timing" (Dodson, 2011; Repp, 1995; see Gabrielsson, 2003 for a review). To see if my expressive timing was related to my PCs, we compared tempo arches in phrases that began with a PC and phrases that did not (Demos et al., 2018). Figure 5 shows that tempo arches were taller and more tilted in phrases with PCs than in phrases without PCs.[iii]

The taller arches indicate that the tempo changed more in phrases with PCs. The tilt indicates that the arch started out slower than it ended, indicating that phrases with PCs started out with larger "breaths" than phrases without PCs. This is consistent with my subjective impression that my thoughts during performance, my PCs, guided my playing. Not that I was deliberately producing tempo arches. I was listening to my sound and thinking about projecting my interpretation of each phrase clearly to the audience. There are many ways to project phrasing besides resorting to timing (articulation, bowing, dynamics, note duration, rhythm, and tone color). The tempo arches were an automatic, unintended effect of my deliberate intention to project my phrasing (see Bangert et al., 2014).

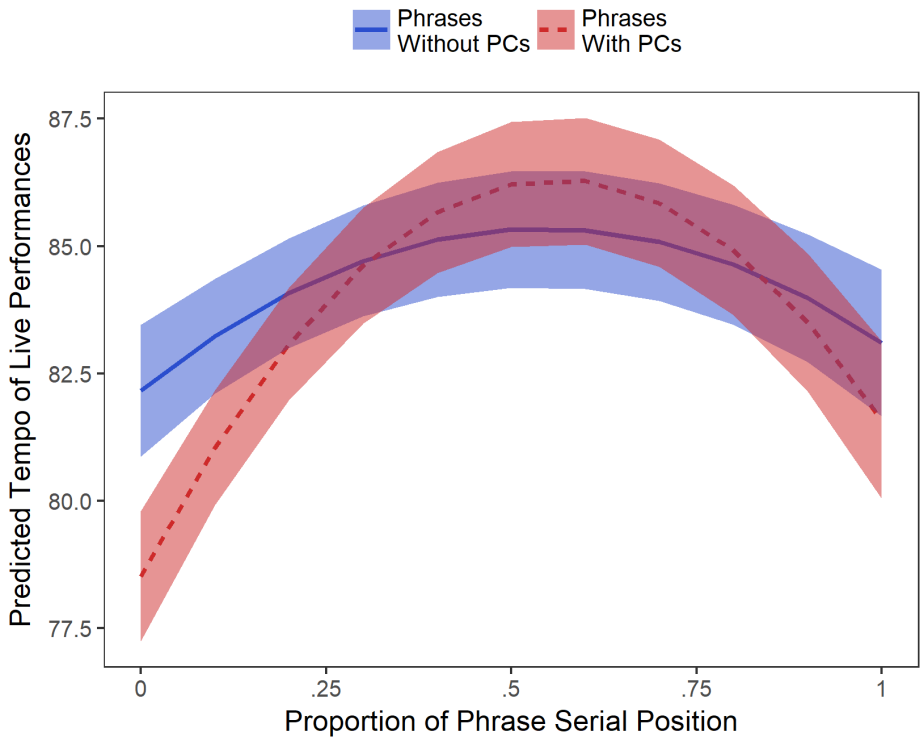

Figure 5. Tempo for seven public performances as a function of serial position of half-bars in phrases with and without PCs.

Memorization and Performance Cues. PCs are both a metacognitive strategy for directing attention during performance and a mnemonic technique. The same thoughts that direct attention also serve as memory retrieval cues, activating the upcoming musical passage in long-term memory. Music performance requires the integration of two forms of memory with very different properties, distinguished in musicians' everyday talk as "learning" and "memorizing" (Chaffin, Demos, & Logan, 2016). On the one hand, there is the procedural memory that develops spontaneously while learning a new piece. For example, when we sing "Happy Birthday", we simply start at the beginning and each line reminds us of the next. Procedural memory develops automatically during practice and is often surprisingly accurate (Rubin, 2006).

However, when performing on stage, procedural memory has two major limitations. First, it is unreliable. Every change in conditions reduces the probability that the action sequence will be completed without interruption. Since practice is radically different from being on stage before an audience, procedural memory is liable to fail when most needed – on stage. Second, the only place to start the action sequence is at the beginning. So, when memory fails and playing stops, the performer is faced with the humiliation of starting again at the beginning. Experienced performers mostly avoid this by learning to start at other places besides the beginning. Then, when something goes wrong, you jump forward and carry on. We refer to this kind of memory as "content addressable" because it is accessed by thinking of its content which provides an address or retrieval cue. Memory addresses are provided by organization which, for music, is provided by the musical structure, or big picture. PCs identify particular locations within this framework where playing can restart, making it possible to recover from a memory lapse.

Memory lapses, and the hesitations they produce, are common on stage. I always find a way forward so that it is never a disaster. For example, I had one hesitation during the first public performance of the Prelude. First performances of new repertoire are always the most challenging ones and, in this case, the venue was difficult, with very dry acoustics and a cold atmosphere. At the start, I found it hard to concentrate. After a few seconds, I became totally involved in the music and in what I wanted to express and what it meant to me. Then, I lost sight, for a second, of what came next in the middle of the piece and missed a couple of notes. Luckily, I was able to get back to my mental map of the score and jump a few notes ahead to my next PC. Not even the other researchers involved in the project noticed the hesitation or realised that I had had a memory lapse.

When I was learning the Prelude, I cannot say that I knew that I was setting up content addressable retrieval cues. For example, in Session 15, I thought I was working on "projection of sound and getting the bow to speak clearly, and … on left hand". However, I had learned from a very early age to practice in short sections and then link the sections together and this is exactly what I did when learning the Prelude. What I learned from our study is that practicing in this way, repeatedly using the same places for starting and stopping, establishes PCs. The places where I started and stopped during practice were the same places that I reported PCs. We were not able to show that these were also places that I jumped forward to when my memory failed during performance, because this rarely happened. However, we were able to show that I jumped forward and restarted at PCs when I tested my memory by trying to write out the score (Chaffin et al., 2010).

I waited until ten months after my 8th performance until my memory for the piece had begun to fade before trying to write out the score. By this time, there were gaps in my memory. As I wrote, I came to places where I was unable to continue. When this happened, I had to jump forward and continue at a later point. These starting points were PCs. This is indicated by the primacy effect anchored on PCs in Figure 6. Recall was highest at the beginnings of phrases and decreased steadily across the rest of the phrase, but only for those phrases that started with PCs, not for other phrases. One explanation is that PCs provided content addressable access to my memory which was otherwise organized as an action sequence. When accuracy was averaged across the whole piece, the probability of recall decreased following a PC because the probability of memory failure increased as serial position in the sequence increased (Chaffin & Imreh, 2002, Ginsborg & Chaffin, 2011; Brown, Neath, & Chater, 2007).

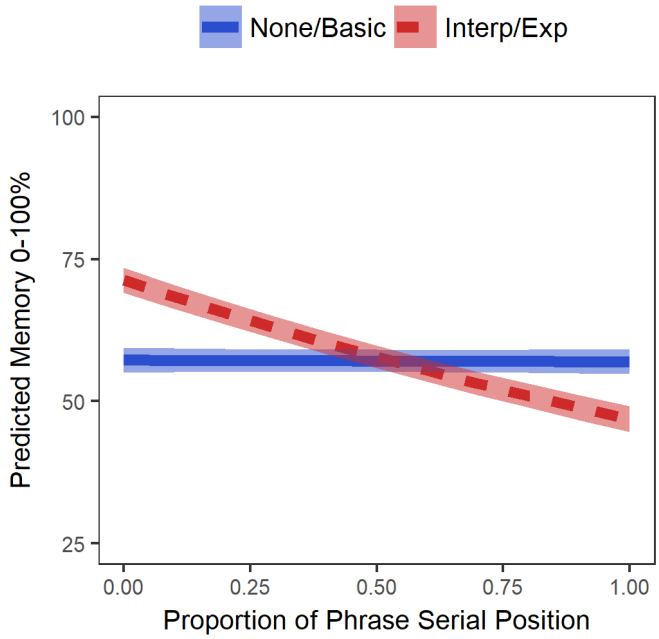

Figure 6. Predicted accuracy of written recall of the score as a function of serial position for phrases with and without Expressive and Interpretive PCs, generated from Model 3.

Figure 6 summarizes a re-analysis of my written recall of the Prelude that parallels the analysis of tempo summarized in the previous section. The new analysis is better suited to the correlated nature of recall data than the multiple regression analyses of these data originally reported by Chaffin et al. (2010; see Demos & Chaffin, 2017 for a discussion). We used the Poisson mixed models, summarized in Table 1, in a forward modeling procedure. Model 1 showed that there was a primacy effect, with recall accuracy decreasing as serial position increased across the phrase. The addition of the effect of PCs in Model 2 did not improve the fit of the model. The significant interaction of serial position and PCs in Model 3 indicated that the primacy effect was larger in phrases with PCs than in phrases without PCs, resulting in a significant improvement in the fit of Model 3 over both Model 1, $\chi^2(2) = 5.77$, $p = .056$, and Model 2, $\chi^2(1) = 5.51$, $p = .019$. The primacy effect anchored on PCs is consistent with the report by Chaffin et al. (2010) of primacy effects anchored on Expressive PCs and starts of phrases (which they refer to as "sub-sections"). The effect suggests that PCs served as retrieval cues, providing content addressable access to memory, allowing me to restart when my memory failed without going back to the beginning.

Table 2**.** *Mixed models of effect of serial position in a phrase on recall accuracy.*

Fixed Factors	**Model 1**	**Model 2**	**Model 3**
(Intercept)	1.249***	1.236***	1.232***
	(0.113)	(0.116)	(0.117)
Serial Position in Phrase	-1.852*	-1.838*	-0.043
	(0.787)	(0.788)	(1.131)
PC		0.027	0.012
		(0.052)	(0.053)
Serial Position in Phrase: PC			-3.765*
			(1.653)
Random Factors (Variance)			
Recall (Intercept)	0.002	0.002	0.002
Serial Position in Phrase| Phrase:Section:Recall	41.322	41.347	46.466
Goodness of Fit			
AIC	2975.089	2976.827	2973.321
BIC	2997.222	3003.386	3004.306
Log Likelihood	-1482.545	-1482.413	-1479.660

***p < 0.001, **p < 0.01, *p < 0.05, ·p < 0.1

Teaching Students to Use PCs?

The understanding gained from the Prelude study of how I learned and memorized helped my learning of other pieces. My practice became more focused and efficient and I felt more confident of my memory (Lisboa et al., 2011). So, when my student, Maria, asked for help in learning how to memorize, I decided to apply what I had learned to helping her. My experience with the Prelude suggested that reporting thoughts during practice and performance might help her to develop the content addressable access to memory that she needed to memorize more reliably (Lisboa et al., 2015). So, I showed her how to report her thoughts. If Maria succeeded in memorizing, it would show that a student of normal ability and motivation can learn an important ingredient of virtuosity: the ability to think about musical goals, rather than focus solely on notes and technique, whilst delivering a memorised performance.

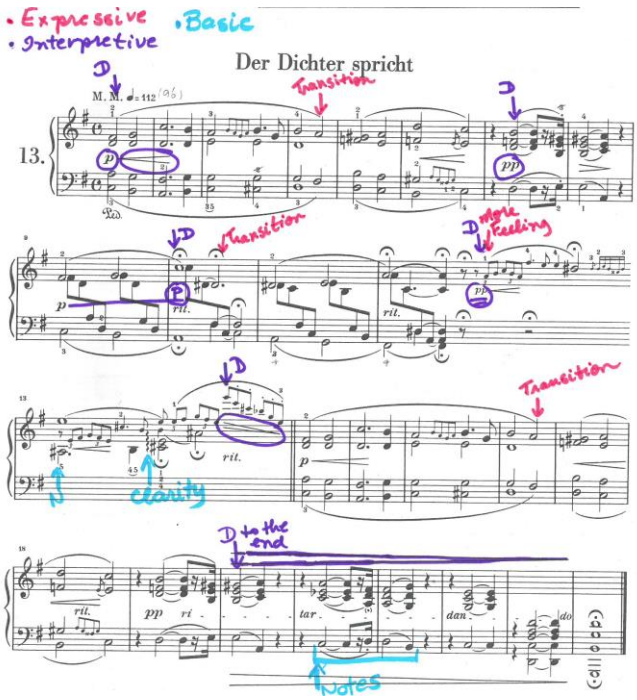

Figure 7. 'Der Dichter spricht' (The Poet Speaks) from R. Schumann's Kinderszenen Op.15. showing thoughts reported for the last week of practice (red = expression, purple = interpretation, blue = basic).

I did not mention PCs, content addressable access, procedural memory, or any of the other theoretical constructs pertaining to memorization discussed above. Instead, I told Maria that writing down thoughts about the music had helped me to memorize and might help her. I asked her to record her practice and we recorded her performances when she played for me during lessons. During lessons, I helped her complete reports on her thoughts during the previous week's practice. When she played for me, I helped her report her thoughts during the performance. The report in Figure 7 is typical. Maria told me which features of the music she had attended to and I marked them on a clean copy of the score, indicating which aspect of the music was involved, e.g., "transition", "feeling", "clarity", using different coloured inks to represent the classification of each feature as involving musical structure, expression, interpretation, or basic technique.

We did this for seven weeks, at which point Maria announced that she had the piece memorized. Shortly after, lessons were interrupted by summer holidays. When lessons resumed, nearly ten weeks later, I asked Maria to play the piece again, from memory. I video-recorded her efforts as she struggled through the piece twice, starting and stopping. These reconstructions from memory appear at the top of Figure 8 which shows all of her playing that was recorded, with her performances during lessons identified by thicker lines, and the reconstruction from memory identified at the top of the figure as "Session 11".[iv]

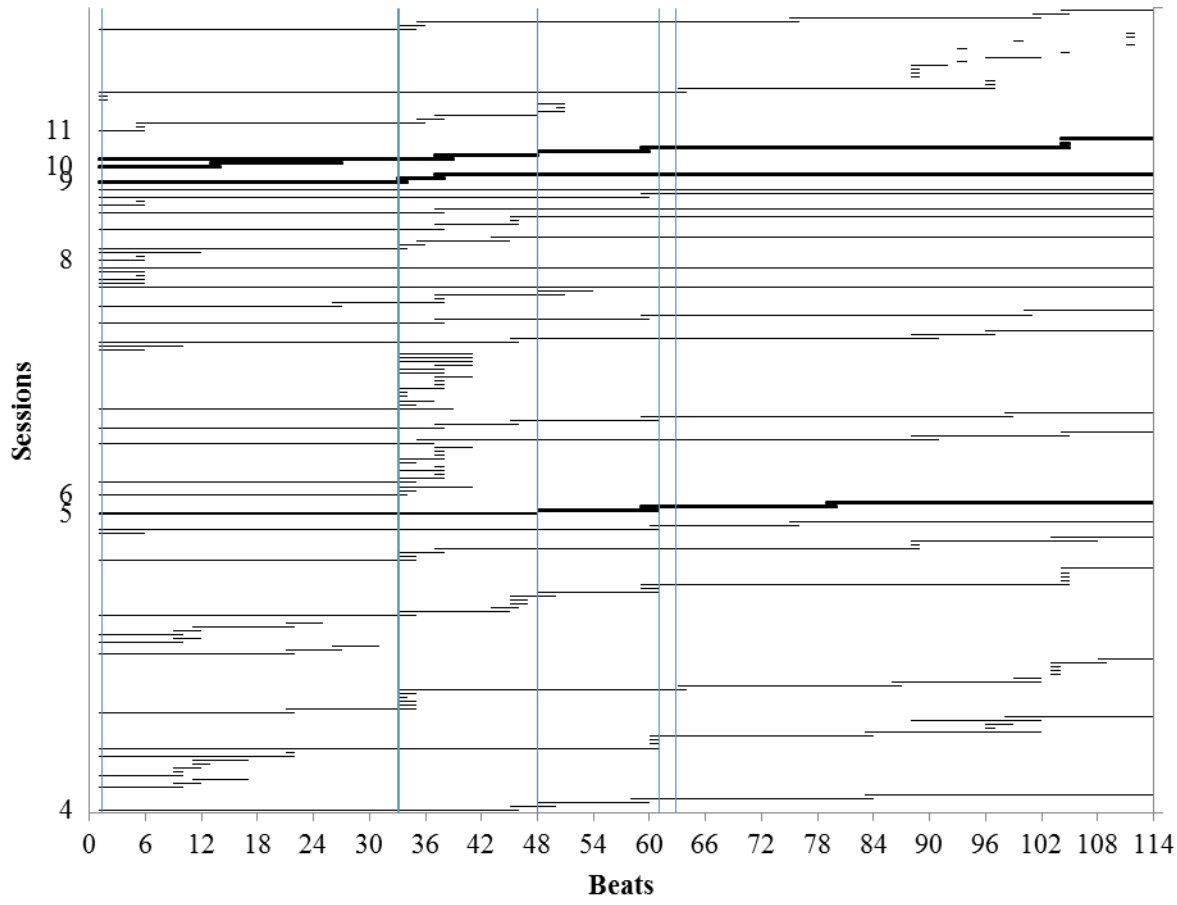

Figure 8. Playing during practice and during lessons, with performances during lessons shown as thicker horizontal lines. Vertical axis shows practice sessions, with each performance and the reconstruction from memory counted as a separate session. Vertical lines show locations of thoughts about expression during the third (last) performance. (Adapted with permission from Lisboa T., Chaffin R., & Demos A.P. (2015). Recording thoughts while memorizing music: a case study. *Frontiers in Psychology*, *1561*(5)).

The first thing to notice about Maria's practice is that it consisted largely of playing through the piece from beginning to end. She rarely stopped to single out short passages for intensive work in the way that I did. Mostly, when she stopped, she backed up a few beats and continued on. Whether this was typical of her practice or whether it was due to the unusual circumstances – perhaps she was performing for the camera – its effect on her performances is clear. They look much like her practice, constantly interrupted by restarts; she never did achieve a fluent, uninterrupted performance.

Second, the vertical lines in Figure 8 represent the location of thoughts that Maria reported for the third (final) performance. Every thought coincides with at least one start or stop; some coincide with many, e.g., beat 33. The preponderance of intersections in Figure 8 suggests that most, if not all, of the thoughts that Maria reported during the performance were PCs, i.e., locations where thoughts prepared during practice provided starting points when her recall failed during the reconstruction from memory. The location of restarts during reconstruction was

reliably related to the location of thoughts during performance and to starts during prior practice (Lisboa et al., 2015). Thus, Maria's thoughts during practice reappeared as PCs during performance and as points of recovery when the motor sequence was interrupted during construction from memory.

Maria learned how to memorize and used PCs to do so. While we do not know whether she would have memorized equally well without reporting her thoughts, her success shows that a student musician of average ability and motivation can learn to use PCs; to think about musical goals, instead of technique, when playing. With appropriate instruction, PCs do not have to be an esoteric technique limited to those of exceptional abilities or with advanced training. Moreover, I observed informally that Maria began playing more expressively and her confidence and willingness to play for others increased. She began to mark her thoughts on the scores of other pieces that she learned, noting that 'this is a much more interesting type of practice than just repeating bits of the music' (Lisboa et al., 2015, p. 12).

Conclusion

It is no accident that performing from memory became an integral part of solo musical performance in the same era that performers, whose names are still remembered today, made their reputations by astonishing audiences with dazzling technique and spell-binding musicality. Clara (Wieck) Schumann and Franz Liszt popularized the practice of playing without a score in the 1830's. Their ability to play long programs from memory astonished audiences then and continues to impress audiences today. Our studies suggest that letting go of the score to play from memory is a relatively small step for a musician who has put in the practice needed to master a challenging musical work. To play expressively when a piece has received extended practice requires many of the same metacognitive skills needed to play from memory. The performer must learn to attend to PCs that provide a mental map of the piece, with the musical transitions as the main landmarks. The map guides problem solving during the many hours of practice required to master a complex piece, guides playing during performance, and provides a safety net that makes it possible to recover when things go wrong.

PCs avoid the danger that the music will "lose its charm" and "seem too prepared, …[and] give the impression of having been heard a hundred times " (Hennion, 2012, p. 127-128). By keeping the performer's attention focused on the artistic image of how the piece should sound, PCs imbue the music with expression. For the Prelude, it was a matter of maintaining the mellow sound and flow of the music while drawing the listeners' attention to the transitions from one musical phrase to another. My PCs at these musical transitions reminded me of my musical goals, e.g., to bring out the "singing" qualities of the melody, ensuring that I remained fully engaged with the music. When a performance is going well, I experience the sound flowing from my cello out into the auditorium as I listen for musical qualities that I have worked to create in my performance. Musical thoughts are in the foreground, technical options in the background, available when needed. This is how a performer learns to play a virtuosic piece with passion and conviction, and from memory. The technical difficulties become invisible and the musical thoughts and feelings make the performance seem magical.

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End Notes

[i] "Playing from memory" means something rather different today than it did for Wieck and Liszt. Wieck started performing without a score after hearing Paganini perform (Reich, 2013, pp 18-36). Paganini played without a score, mostly playing his own works or improvising freely on the works of others, as did Liszt (Kawabata, 2013, pp. 21–23). Wieck also played her own works (e.g., May, 1912, p. 82), but her performances may have been closer to what we mean today by "from memory" (i.e. reproducing the score without relying on improvisation). The uncertainty reflects a wider development in music performance practice occurring during this period, the emergence of the modern idea of a musical "work" as a stable entity that persists unchanged across performances and performers (Goehr, 1992). The emergence of memorization was one reflection of this change, which was also reflected in a decline in improvisation and the growing practice of writing out cadenzas, as Mendelssohn did for his violin concerto in 1844.

[ii] We provide a new timeline of the Prelude study (Table 1), new examples of the cellist's practice and reports (Figures 2 and 4 respectively), a new graph of phrase arches for tempo in the cellist's public performances (Figure 5), a new analysis of her written recall of the score (Figure 6 & Table 2), and a new example of the piano student's reports (Figure 7). We reproduce previously published graphs of the cellist's and piano student's practice (Figures 1, 3 & 8).

[iii] In Figure 5, the data are collapsed across performances. Demos et al. (2018) provide a more complex figure (Figure 4) showing how the effect of PCs at starts of phrases developed over time in successive performances.

[iv] I did not ask Maria to write out the score from memory, as I had, because I thought the task would be too difficult. I was able to write out the score because I learned to transcribe music as a student. Maria had no such training and a piano score is harder to write out than a score for a single line instrument. We do not report my reconstruction the score from memory, as we do for Maria, because, when I did so, I was too successful (Lisboa, Chaffin & Logan, 2009). To my surprise, my playing was almost error-free, providing no opportunity to observe recoveries from memory failure.