# Learning *Clair de Lune*: Retrieval Practice and Expert Memorization

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**How does an experienced** performer memorize when learning a new piece quickly, in just a few hours of practice? To find out, a concert pianist recorded her practice as she learned *Clair de Lune* by Claude Debussy. She also provided detailed reports on the formal structure of the piece, the performance cues that she selected to attend to while playing, and other decisions about technique and interpretation. These reports were used to determine what she paid attention to during practice and where she had difficulty with memory retrieval. Retrieval practice was one of the main activities throughout the 4¾ hours needed to prepare the piece for performance. The pianist tried to play from memory almost from the start, used the musical structure to organize practice, and worked on performance cues to speed up retrieval from long-term memory. Performers practice memory retrieval, even when practice time is limited.

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**The biographies of famous musicians** are full of amazing tales of memory feats (e.g., Cooke, 1999, p. 41). Experts in other domains exhibit a similar ability to memorize with an efficiency that seems almost superhuman (Chase & Simon, 1973). According to expert memory theory, however, experts' memories work in the same way as everyone else's. The extraordinary memory abilities of experts can be explained in terms of general principles of memory functioning that apply to everybody (Chaffin & Imreh, 2002; Ericsson & Kintsch, 1995). Superior memory is due to a combination of (1) knowledge, (2) strategy, and (3) effort. First, experts' knowledge of their domain of expertise allows them to encode new information in terms of ready-made patterns (chunks) already stored in memory (Mandler & Pearlstone, 1966; Miller, 1956; Tulving, 1962). For a musician, chunks include familiar patterns like chords, scales, and arpeggios, whose practice forms an important part of musical training (Halpern & Bower, 1982; Imreh & Chaffin, 1996/97). Second, expert memorists use a retrieval scheme to give them access to the chunks that make up their memory for a piece when it is needed (Ericsson & Oliver, 1989). Third, prolonged practice increases the speed of retrieval dramatically, to the point where an expert can rely on long-term memory to perform tasks for which most people rely on working memory (Ericsson & Kintsch, 1995).

It is not obvious that principles of expert memory would apply to musical performance, since those principles were derived from studies of experts memorizing things like chess boards (Chase & Ericsson, 1982; Chase & Simon, 1973), digit strings (Chase & Ericsson, 1982; Thompson, Cowan, & Frieman, 1993), and dinner orders (Ericsson & Oliver, 1989). In these domains, declarative (conceptual) memory is primary, while motor and auditory memory are relatively unimportant. In music performance, in contrast, motor and auditory memory are primary. Most performances in the Western art music tradition are highly practiced, providing the musician with an automatic, implicit memory of the motor sequences required. The pianist Jörg Demus suggested that, in their youth, most performers probably rely almost entirely on motor memory: "When you are young, you play ['by heart'] almost unconscious of what you are doing . . . But at a later age . . . this unconscious approach doesn't work any more so we have to support the heart by the 'brains'" (Elder, 1986, p. 129).

The problem for anyone relying on implicit motor memory, whether student or professional, is that when something does go wrong, as it will eventually, the musician has no recourse and must muddle along, improvising, hoping that something will provide a retrieval cue to get the performance back on track. Demus apparently believed that the risk of public humiliation involved in a memory failure on stage eventually leads most young performers to develop more reliable memory strategies. Using the "brains" is a matter of supporting the largely

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implicit motor memory with a more explicit, declarative memory. As the pianist Leon Fleischer put it: "Probably the least reliable [form of memory], in terms of public performance, is finger memory, because it's the finger that deserts one first. So I would think in terms of structural memory . . ." (Noyle, 1987, p. 97).

Fleischer's comment suggests that an experienced musical performer's declarative memory for a piece may be very much like the memories of the expert chess players, digit-string-memorists, and waiters studied in earlier research (e.g., Ericsson & Kintsch, 1995; Ericsson & Lehmann, 1996). Most Western art music is hierarchically organized into movements, sections, and subsections on the basis of the harmonic and melodic properties of the musical material. This formal structure provides musicians with a ready-made retrieval scheme that can be used to provide reliable and flexible access to their memories for the music. Studies of musical memory show that musicians encode music in terms of this structure by using it to organize their practice. By starting and stopping at section boundaries, musicians establish these points as retrieval cues. If something goes wrong during a performance, the musician can jump to the next retrieval cue and continue with minimal disruption (Chaffin & Imreh, 1997, 2001, 2002; Chaffin, Imreh, & Crawford, 2002). Experienced performers pay attention to musical structure during practice, resulting in memory representations that are hierarchically organized in terms of structure: beginnings of sections are recalled better (Chaffin & Imreh, 1997, 2002; Chaffin et al., 2002), and recognized faster (Williamon & Egner, 2004).

In addition to section boundaries, experienced musicians set up other retrieval cues to guide their performance. These *performance cues* represent four main aspects of a piece of music (Chaffin & Imreh, 1997, 2002; Chaffin et al., 2002; Chaffin, Lemieux, & Chen, in press). I have already mentioned the s*tructural* cues that represent section boundaries. Another kind of structural cue is a *switch,* where the same musical material repeats at different points in the piece and there is a risk of confusing which passage is being played. *Expressive* cues represent the musical feelings to be conveyed to the audience, e.g., surprise or excitement. Expressive cues provide another level in the organizational hierarchy, dividing a piece into expressive phrases. In addition, there are performance cues for interpretation and technique. Most of the decisions a musician makes about interpretation and technique are implemented automatically as a result of practice. A small number, however, may need monitoring during performance to ensure that they are executed as planned. These become the *interpretive* and *basic performance cues*. Interpretive cues represent critical interpretive decisions, e.g., a decrease in dynamics that prepares for a later crescendo. Basic cues represent critical details of technique, e.g., the use of a particular fingering to position the hand for what follows.

Figure 1 shows an example of performance cues used by the pianist in the present study. The figure shows the basic, interpretive and expressive cues (represented by arrows)

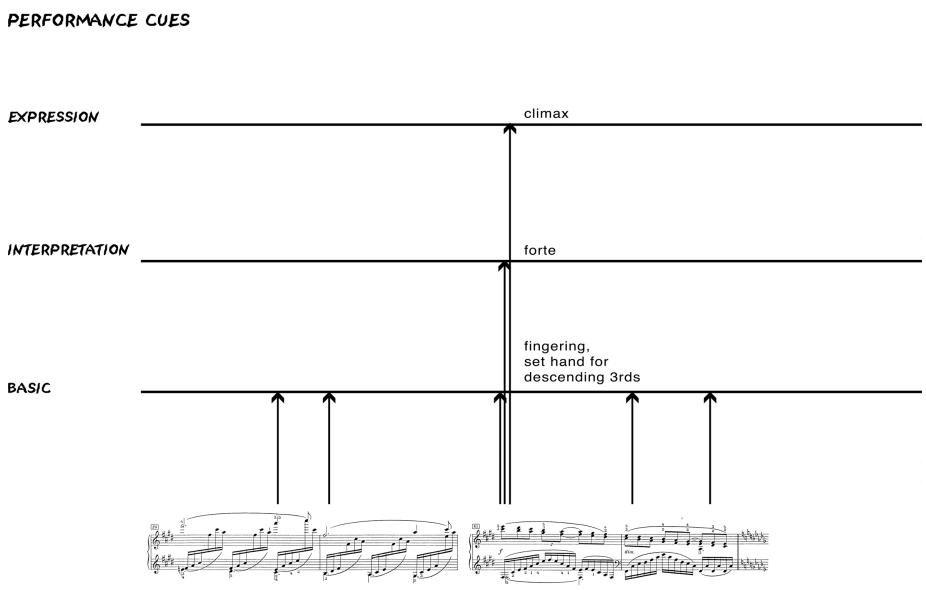


FIGURE 1. An example of the pianist's original report of performance cues (indicated by arrows) for bars 39-42 of *Clair de Lune* by Claude Debussy, with annotations added by the author.

for bars 39-42 from *Clair de Lune* by Claude Debussy, with annotations added by the author for purposes of illustration. Three performance cues are marked at the beginning of bar 41. This was, for the pianist, the expressive climax of the piece. At the basic level she needed to position her hand for the series of descending thirds that follow. At the interpretive level, she needed to play forte. At the expressive level, she had to convey the expressive climax. The three types of cues thus represent different ways of thinking about the same point in the music. In this bar, the three types of cues worked together, but cues are not always aligned in this way. Four additional basic performance cues in Figure 1 represented familiar harmonic relationships that were important landmarks but did not involve special attention to interpretation or expression. Interpretive and expressive cues may also occur alone.

Performance cues are landmarks that an experienced musician uses to monitor a piece as it unfolds during performance. They form a mental map that provides a way of monitoring and controlling the rapid, automatic actions of the hands, giving the musician the flexibility to recover from mistakes and adjust to the idiosyncratic demands of each performance. Thinking about performance cues during practice provides the musician with practice in memory retrieval. Paying attention to a feature of the music establishes it as a retrieval cue so that during performance, the cue comes to mind automatically and effortlessly during performance, and elicits the highly practiced movements of fingers, hands, and arms required at that point.

Extended practice is needed for performance cues to function reliably under the pressures of the concert stage (Chaffin et al., 2002). To be useful during a live performance, retrieval from declarative long-term memory must keep pace with the speed of the performance. However, this kind of memory retrieval is normally a slow process relative to perceptual and motor processes (Ericsson & Kintsch, 1995). This is why inexperienced performers rely on implicit motor and auditory memories instead. In order to maintain an explicit, declarative representation in working memory during performance, the performer must be able to think ahead to what comes next as the piece unfolds. Without sufficient practice, the musical flow is constantly disrupted as the performer hesitates in order to recall the next passage before playing it. Extended practice is needed to avoid these interruptions and make retrieval from declarative long-term memory rapid, automatic, and reliable. Achieving the necessary integration of thought and action is one of the main goals of the long hours of practice required to learn a challenging piece of music.

Studies of musicians learning new works confirm that they engage in extended practice of performance cues. In a study of student pianists, the more advanced students began using the musical structure to organize their practice earlier in the learning process than the less advanced, providing them with more practice of structural cues, resulting in better performances (Williamon & Valentine, 2002). Longitudinal case studies of experienced performers show that they practice performance cues from the beginning when learning a new piece. A pianist and a cellist both practiced performance cues throughout the more than 30 hours and 50 practice sessions needed to learn, respectively, J. S. Bach's *Italian Concerto (Presto)* and *Cello Suite VI (Prelude)* for performance (Chaffin et al., 2002; Chaffin, Lisboa, Logan, & Begosh, 2006).

What about music that does not require such prolonged practice? Experienced performers often learn new pieces very quickly. Does this faster memorization also involve extended practice of retrieval cues? Two longitudinal case studies of experienced performers learning easier works over relatively short time periods suggest that performance cues are an important focus of practice for easier works (Ginsborg, Chaffin, & Nicholson, 2006; Noice, Chaffin, Jeffrey, & Noice, in press). The need for extended practice of performance cues is reduced, compared to more difficult pieces, because fewer cues are needed and because the cues do not need to operate so quickly. Practice of performance cues is, however, still important. Ginsborg et al. (2006) describe the comments of a soprano and conductor in individual and joint practice sessions as they prepared to perform Stravinsky's *Cantata (Ricercar I)* for soprano and tenor soloists, women's choir, and instrumental ensemble. The musicians' comments identified locations they later reported as performance cues, and in the joint sessions the musicians negotiated agreement about the performance cues that they shared. Noice et al. (in press) observed a jazz pianist memorizing a 32-bar bebop standard, *In Deep Freeze* by Hank Mobley, in two sessions totaling 45 minutes. Structural, expressive, and basic performance cues were singled out as starting places. Experienced performers appear to use performance cues with easier pieces as they do with more challenging works.

The goal of the present study was to further test the hypothesis that experienced performers practice performance cues when learning a piece relatively quickly. The studies described above each reported a single type of evidence: comments (Ginsborg et al., 2006) and starts and stops during practice (Noice et al., in press). In addition, the pianist in Noice et al.'s study did not perform the piece and stopped practicing when it was memorized but

before it was ready for performance. The present study examined four types of evidence as the same pianist studied by Chaffin et al. (2002) prepared *Clair de Lune* by Claude Debussy for public performance for the first time. Although *Clair de Lune* is similar in length to the Bach *Presto*, the pianist expected that it would be much easier to memorize because its slow tempo allows plenty of time to think about what comes next, and because, unlike the *Presto*, its simple, non-repetitive structure provides fewer opportunities for confusing different repetitions of the same theme. The question was whether the pianist would use performance cues and musical structure to help her remember *Clair de Lune* in the same way that she did for the *Presto*.

If the pianist used performance cues and musical structure to memorize *Clair de Lune*, then we will find that starts, stops, and repetitions during practice occur at performance and structural cues more than at other locations. If the pianist practiced using performance cues to remember what happens next, then we will find that hesitations during early practice performances occur at performance cues more than at other locations. We will also look at the pianist's spontaneous comments to the camera during practice to see how her own descriptions of how she was memorizing matched what can be inferred from her playing. Finally, we will look at the proportion of practice time spent thinking rather than playing, to argue that the pianist practiced memory retrieval continuously during practice.

## Method

### *The Pianist*

Gabriela Imreh was trained in classical piano in Romania and lives in the US performing as a concert pianist.

### *The Music*

*Clair de Lune* from the *Suite Bergamasque* by Claude Debussy is one of the most beloved pieces in the piano repertoire. Its ability to evoke feelings of tranquility, mystery, and pathos have made it popular for generations and led to its selection by the pianist as an encore piece. The pianist had never learned *Clair de Lune* for performance, although she was very familiar with this well-known piece and had played other works by Debussy throughout her career. Although harmonically complex, *Clair de Lune* contains few technical difficulties and its simple *ABBA* song structure is easily grasped. It takes about 5 minutes to perform and is scored in 72 bars in 9/8 time.

### *Procedure*

#### PRACTICE SESSIONS

The pianist recorded her practice from the first time she sat down at the piano until the first public performance two weeks later. Sessions 1-5 took place in the practice studio and were recorded on videotape; Sessions 6-7 were in the concert hall on the day before and the day of the first public performance and were recorded on audiotape. The public performance was not recorded. The pianist did not engage in systematic mental practice and did not study the score away from the piano, so our data cover the entire process of preparing the piece. The learning of *Clair de Lune* took place during a 3-month break (between Sessions 12 and 14) in the learning of the Bach *Presto* described by Chaffin et al. (2002, pp. 97-100). At this time the pianist had not yet formulated the idea of performance cues that she first articulated four months later as part of a description of how she memorized the *Presto*.

Practice was transcribed by recording the location of each start and stop during practice. During practice the pianist commented periodically on what she was doing and these comments were transcribed and classified by topic (see Chaffin et al., 2002, pp. 140-141).

The mean *target tempo* of playing in each session was measured by adjusting an electronic metronome until it corresponded to the tempo of playing at ten points in each session, spaced at roughly equal intervals. At each point, the tempo measured was the target tempo that the pianist was aiming to play the segment at, ignoring momentary pauses and hesitations. The *practice rate* in each session was the mean number of beats played per minute across the whole session (number of practice segments × mean length of practice segments in bars × 3 beats/bar)/(playing time in minutes). Playing time was the duration of the session recorded on tape minus time spent not playing at the beginning and end and any breaks in playing of more than 30 seconds. The *rate/tempo ratio* expressed the discrepancy between the rate of practice and the target tempo (rate of practice/target tempo; see Chaffin et al., 2002, pp. 126-135 for details on each of these measures).

#### PRACTICE PERFORMANCES

The first few times the pianist played through the piece from memory were punctuated by hesitations. Six practice performances in which she played through the piece without interruption were examined to see where the hesitations occurred, two from each of Sessions 4, 5 and 7. Data from these performances were combined by computing a mean tempo for each bar across performances to

**TABLE 1. Practice dimensions used by the pianist.**

| Dimension | Description |
|---|---|
| Musical Structure | *Section boundaries*: beginnings and ends of musical themes, dividing the piece into sections<br>*Switches*: places where two repetitions of the same theme begin to diverge |
| Performance Cues | *Expressive*: emotion to be conveyed during performance, e.g., tension, peacefulness<br>*Interpretive*: phrasing, dynamics, tempo, and use of pedal still requiring attention in performance<br>*Basic*: familiar patterns, fingering, and technical difficulties still requiring attention in performance |
| Interpretation | *Phrasing*: grouping of notes to form musical units<br>*Dynamics*: changes of loudness, or emphasis of a series of notes in order to form a phrase<br>*Tempo*: variations in speed<br>*Pedal*: used to color the sound by controlling its resonance and duration |
| Basic Technique | *Fingerings*: non-standard choices about which fingers to use to play particular notes<br>*Technical difficulties*: places requiring attention to motor skills (e.g., jumps)<br>*Familiar patterns of notes*: e.g., scales, chords, arpeggios |

form two mean performance phases. *Earlier performances* (two from Session 4 and one from the beginning of Session 5) were representative of the initial practice performances in Sessions 4 and 5. *Later performances* (the last performance in Session 5 and the two from Session 7) were representative of the more polished playing in Sessions 6 and 7. The pianist reported, after listening to the recordings, that the later performances were close to the interpretation she was aiming for.

Inter-bar intervals (IBI, in seconds) were measured for each performance with a commercial sound wave processing program, from the start of the first note sounded in each bar to the start of the first note of the next, and converted to tempo estimates in beats per minute (tempo = (1/IBI seconds) ∗ 3 ∗ 60).[1]

### PIANIST'S REPORTS

The pianist reported the features of the music that she attended to or made decisions about during practice approximately six months after the performance, while the piece was still active in her repertoire. The reports were organized into 12 dimensions that represented all the aspects of the music that the pianist considered (see Table 1; see Chaffin et al., 2002, pp. 166-176 for details). *Structural* dimensions described the pianist's understanding of the thematic organization of the music (section boundaries[2] and switches). *Performance* dimensions described the performance cues the pianist attended to as she played (expressive, interpretive, basic). *Interpretive* dimensions shaped the musical character of the piece (phrasing, dynamics, tempo, and pedaling). *Basic* dimensions required attention just to produce the notes (familiar patterns, fingering, and technical difficulties).

The pianist made the reports by marking copies of the score that were cut into short sections and pasted onto larger sheets of paper. An example of the pianist's report of the basic dimensions is shown in Figure 2, for bars 39-42. Arrows indicate features of the music that the pianist had thought about during practice, distinguishing technical difficulties, fingering, and conceptual units (called "familiar patterns" in Table 1 and elsewhere for greater clarity), which are marked on separate dimensions. Interpretive dimensions and performance cues were similarly reported on two additional sheets. The report of performance cues for the same bars is shown in Figure 1.

Bars 39-42 represented the climax of the piece and the attention the pianist devoted to this crucial passage is reflected in the large number (33) of basic features marked in Figure 2. Note, however, that only five basic performance cues are reported for the same passage in Figure 1. This was typical; basic performance cues were a highly selected subset of basic features. Most basic features became automatic with practice so that they no longer needed attention during performance. Only a small number of basic features that the pianist chose to think about as part of her mental map of the performance became basic performance cues.

[1] In bars 1 and 9, there is no note sounded at the beginning of the bar. In these cases the beginning of the bar was located by interpolation.

[2] The pianist identified the following sections and subsections (with bar numbers in parentheses): Aa (1-8), $Aa^1$ (9-14), Ab (15-19), $Ab^1$ (20-26), Ba (27-30), $Ba^1$ (31-42), $Ba^2$ (43-50), $Aa^2$ (51-58), $Aa^3$ (59-65), Coda (67-72).

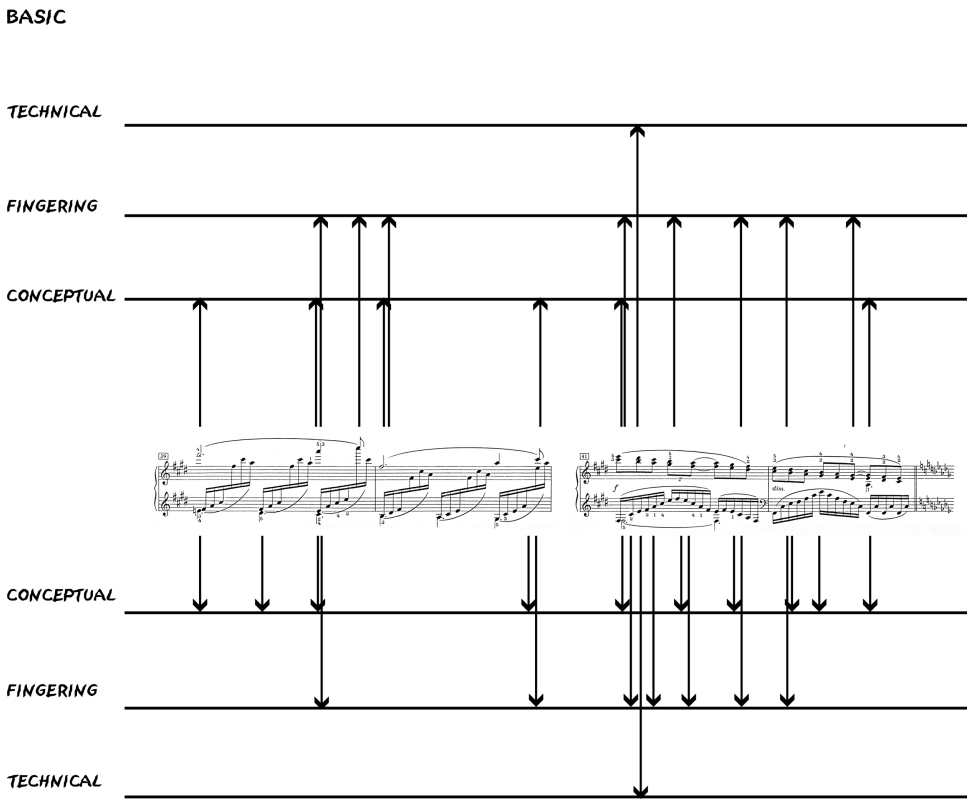


FIGURE 2. An example of the pianist's original report of features involving basic technique that she thought about during practice for bars 39-42, separated onto three dimensions (technical difficulties, fingering, and conceptual units/familiar patterns). Features are indicated by upward and downward pointing arrows for the upper and lower staves respectively.

## ANALYSIS

To determine whether the pianist was practicing the performance and structural cues that she identified in her reports, multiple regression analyses were used to relate the number of performance cues reported for each bar to how much each bar was practiced and how fluently each bar was played from memory in practice performances. Dependent variables were the amount of practice (number of starts, stops, and repetitions of each bar) and the bar-to-bar tempo of practice performances. Predictor variables representing the pianist's reports of musical structure, performance cues, and features on the interpretive and basic dimensions (see Table 1) were all entered simultaneously. Eleven predictors relevant to the present hypotheses about memorization were selected on the basis of exploratory analyses that included all 22 of the predictors described in the next paragraph.

The 12 dimensions in Table 1 provided 21 predictors, and the number of notes in each bar was also included as a predictor in all analyses. Reports of musical structure were represented by five predictors: the first and last bar in each section (coded with dummy variables), serial position of a bar in a section numbered from the beginning of the section, the number of switches reported in a bar, and bars before switches. Basic, interpretive, and expressive performance cues were each represented by three predictors. Reports of performance cues were coded by the number of cues reported per bar for each dimension. To identify effects on neighboring bars, bars before and after basic, interpretive, and expressive performance cues were represented by lagging the relevant predictors one step (bar) forward and backward. For example, to represent bars before and after basic performance cues, the variable representing basic performance cues was moved one row up (before) and one row down (after) in the data matrix, creating two new predictors representing, respectively, bars before and after basic performance cues. (Bars before switches, mentioned above, were coded in the same way by lagging forward). Finally, reports of interpretive and basic dimensions were coded by the number of features

reported per bar for each interpretive dimension (phrasing, dynamics, tempo, and pedal) and each basic dimension (fingering, technical difficulties, and familiar patterns).

The predictors selected for practice and tempo on the basis of the exploratory analyses were slightly different. For both practice and tempo, structure was represented by first and last bars in sections and by serial position, performance cues by the number of cues of each type (basic, interpretive, expressive), and number of notes was also included. In addition, analyses of practice included: bars before and after basic performance cues, bars before interpretive cues, and bars after expressive cues. The same predictors were used for tempo with the addition of switches and the omission of bars before basic cues, making a total of 11 for both practice and tempo.

Correlations between predictors were mostly small ($r < .20$). The most substantial correlations were between measures of structure ($r < .53$), and between expressive cues, interpretive cues, and beginnings of sections ($r < .36$). In five other cases $r < .30$ and $> .20$. The number of bars containing the different kinds of features and cues used as predictors varied: section boundaries (10), switches (7), basic cues (56), interpretive cues (34), expressive cues (16). Predictors involving serial position and number of notes varied continuously with values in every bar.

## Results & Discussion

### *Stages of Practice*

Preparation of the piece took seven practice sessions, totaling 4¾ hours, over two weeks, including an 8-day break while the pianist traveled to give a recital. Table 2 shows the distribution of sessions across the two-week learning period, the duration of each session, and the length and number of practice segments (episodes of uninterrupted playing) in each session. Figures 3-5 show the practice for all seven sessions, with each practice segment on a different line. The records read from bottom to top with each line representing the uninterrupted playing of the bars indicated on the horizontal axis. Each time playing stopped and restarted, a new segment is shown on the next line up. (The beginning of the first practice segment of each session is indicated to the left by ">"). Learning was divided into four stages on the basis of the practice graphs; the statistical summaries are reported below, as well as the pianist's comments during practice.

#### SCOUTING-IT-OUT (SESSION 1)

The pianist began in Session 1 by reading through the score (not shown in the practice graph) and then sight-reading through the whole piece with many interruptions, but without stopping to work on anything. This concluded the first stage of *scouting-it-out* in which the pianist formed a musical image of the piece and identified the main landmarks and issues to be dealt with (Chaffin, Imreh, Lemieux & Chen, 2003; Neuhaus, 1973).

#### SECTION-BY-SECTION (SESSIONS 1-3)

The next stage of *section-by-section* practice lasted through Session 3. The pianist worked through the piece in sections, dividing the *A* theme into its two main subsections, working first on bars 1-14 and then on bars 15-26, before putting the two together. She then did the same for the *B* theme in bars 27-50. Session 1 concluded with another attempt to run through the whole piece. In Session 2, the pianist began by touching up passages already worked on and then focused on the climax of the piece in bars 41-42, setting up the performance cues shown in Figure 1. This work was unfinished when the pianist ran out of energy:

> "*I wish I had a little more stamina to work some more. I am sure I could get it done pretty soon. [But] I am also very tired . . . I'll try tomorrow. I hope I get a little time to work on it.*"

**TABLE 2. Practice session and segment characteristics across the two-week learning period.**

| | Stage | | | | | | |
|---|---|---|---|---|---|---|---|
| | Section-by-section | | | Putting-together | | Polishing | |
| Descriptive statistic | Session 1 | Session 2 | Session 3 | Session 4 | Session 5 | Session 6 | Session 7 |
| Days from start of practice | 1 | 2 | 3 | 11 | 12 | 13 | 14 |
| Session duration (hrs:min.) | 1:06 | 0:36 | 0:33 | 0:55 | 0:56 | 0:30 | 0:13 |
| Mean segment length (bars) | 4.3 | 4.3 | 5.0 | 16.3 | 23.5 | 11.8 | 19.5 |
| Number of practice segments | 172 | 111 | 89 | 40 | 33 | 33 | 9 |

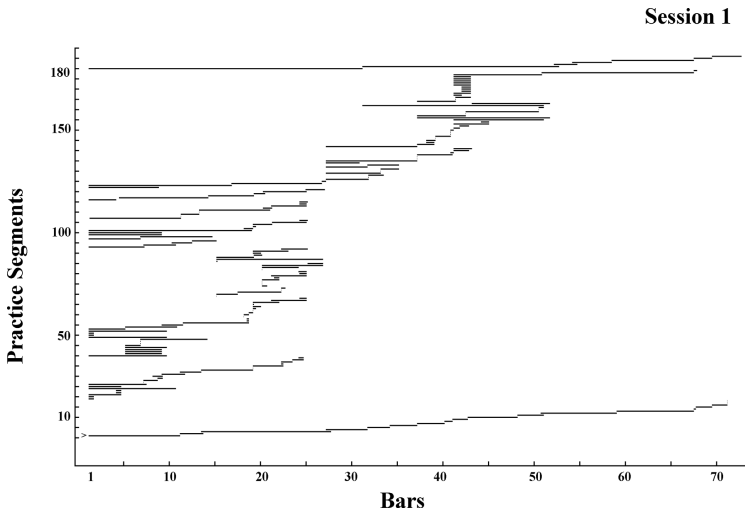


FIGURE 3. Cumulative practice record for Session 1, indicating where playing started and stopped. The record reads from bottom to top.

She did not, and the following day had to travel for a recital. When she returned eight days later, work on bars 41-42 resumed in Session 3, which concluded with three run throughs as far as bar 50.

PUTTING-TOGETHER (SESSIONS 4-5)

Although the pianist had not yet completed section-by-section practice for the last section, in Session 4 she moved on to the next stage in which the goal was to play the whole piece from memory. Session 4 began with an effort to play through as far as possible from memory, and ended with four successful runs through the entire piece without the score. Session 5 followed the same pattern, with work on the neglected final section fitted in between practice performing from memory.

POLISHING (SESSION 6)

Warming up with two runs through *Clair de Lune* for a practice session in the recital hall the day before the concert, the pianist found that the final section was still giving trouble:

> "*Of course, the last page is still the weakest, because I started it much later than the rest and worked on it less*" (Session 6).

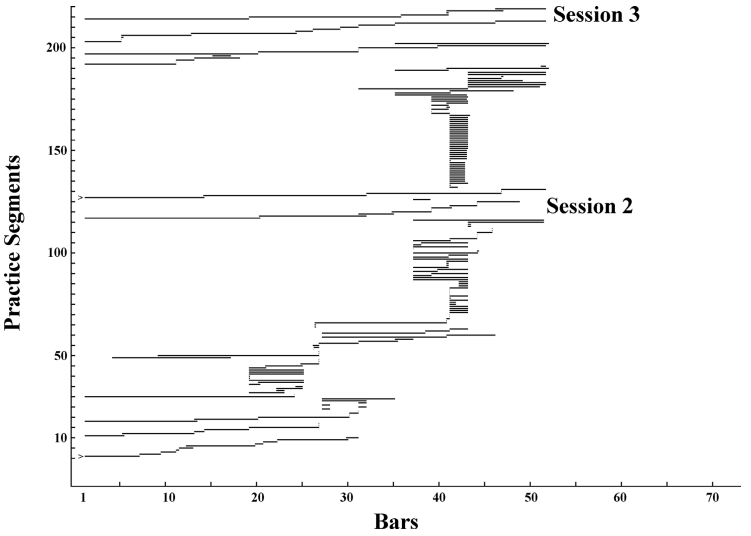


FIGURE 4. Cumulative practice record for Sessions 2-3, indicating where playing started and stopped. The record reads from bottom to top.

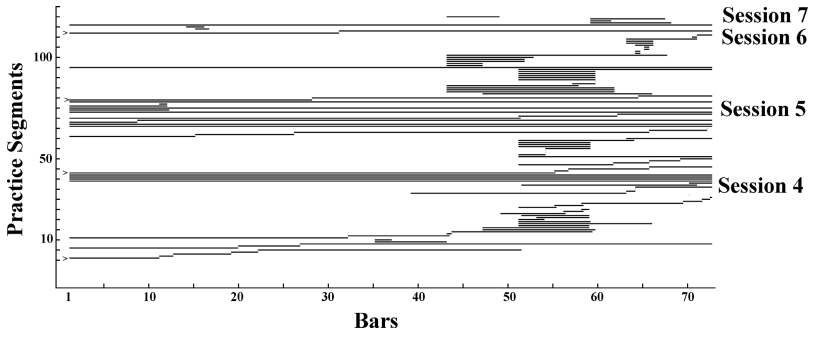


FIGURE 5. Cumulative practice record for Sessions 4-7, indicating where playing started and stopped. The record reads from bottom to top.

She repeated the same procedure again the following morning (Session 7) and performed the piece as an encore in the recital that afternoon. Two days after the performance, the pianist recorded her evaluation of her playing:

> "*It went quite well for a first performance . . . I made a few very small mistakes. And, actually, I felt quite comfortable. Probably the only memorable mistake that bothered me a bit was in bar 33, and it just meant that I hung on to it. But for a minute, a second, a split second, I was a little bit worried. I can't even tell where the mistake was, whether it was in right hand or left hand. I recovered very fast. It was just a split second decision and I knew what I was doing . . . Other than that, it was very eventless . . . So, I think it's been quite a good job*."

She planned to perform *Clair de Lune* again in another concert a month later, but for now the piece was memorized and the pianist stopped recording her practice.

### *Descriptive Measures of Practice*

The differing goals of each stage are reflected in changes in the number and length of practice segments in each session (see Table 2). In Sessions 1-3, practice segments were short and numerous as the pianist worked through the piece in sections. In Sessions 4-5, segments increased in length and decreased in number as she practiced performing without interruption. In Sessions 6-7, segment length decreased again because the pianist was polishing details and did fewer practice performances.

### *Effects of Musical Structure and Performance Cues on Practice*

It is evident in the practice graphs that the pianist preferred some places for starting and stopping and that she practiced some passages more than others. Why? The answer is suggested by the regression analyses summarized in Table 3. The significant positive effects indicate that the pianist started at, stopped at, or repeated bars where she reported structural boundaries and performance cues more often than other locations.

Practice was organized by the formal structure. In all three stages, practice segments started at section boundaries more than at other locations. The effects in Table 3 show that, as in her learning of the *Presto*, the pianist had the formal structure in mind during practice and was establishing beginnings of sections as retrieval cues where she could initiate playing (Chaffin & Imreh, 2002; see also Miklaszewski, 1989; Williamon & Valentine, 2002). The effect of serial position in Sessions 1-3 suggests that attention to the formal structure was already affecting memory in these initial sessions. Bars later in a section were repeated more and were the location of more starts and stops, suggesting that they were harder to remember. Serial position effects of this sort are commonly found in recall data and are generally taken to reflect the organization of information in memory (e.g., Rundus, 1971). Here, the effect suggests that the pianist's memory was organized into chunks based on the sections of the formal structure, and that retrieval of each section began with the first bar, with each bar cuing recall of the next (Broadbent, Cooper & Broadbent, 1978; Roediger & Crowder, 1976).

Throughout the learning process, the pianist focused on performance cues. Basic performance cues and bars following them were repeated more than other bars in Sessions 4-5 and 6-7; in Sessions 4-5, bars before basic cues also were repeated more. The pianist's efforts to play longer passages from memory in these sessions apparently were interrupted by repetition at these points, suggesting that memory retrieval was not yet working reliably.

The effects of expressive performance cues were similar to those for the beginnings of sections in Sessions 1-3; practice stopped at bars after expressive performance cues more than at other locations. The similarity with the effects of musical structure suggests that expressive

**TABLE 3. Regression coefficients (unadjusted) and $R^2$ for effects of the predictors on the number of repetitions, starts, and stops during practice.**

| | Section-by-section Sessions 1-3 | | | Stage Putting-together Sessions 4-5 | | | Polishing Sessions 6-7 | | |
|---|---|---|---|---|---|---|---|---|---|
| Predictor variable | Repetitions | Starts | Stops | Repetitions | Starts | Stops | Repetitions | Starts | Stops |
| *Musical structure:* | | | | | | | | | |
| Beginning of section | 17.22** | 7.16 | 9.94** | −1.25 | 1.98* | −0.33 | −0.79 | 2.33** | 0.89 |
| End of section | 3.58 | −4.07 | 7.92* | −2.38 | 0.23 | 1.21 | −1.87 | −0.33 | 0.25 |
| Serial position in section | 4.31*** | 2.12*** | 1.99*** | −0.11 | 0.05 | −0.03 | −0.36 | 0.03 | −0.01 |
| *Performance cues:* | | | | | | | | | |
| Basic | −4.17 | −2.52 | 2.48 | 3.20** | 0.16 | 0.11 | 3.21** | 0.26 | −0.02 |
| Basic: bar before | 0.01 | 1.43 | −0.51 | 3.34** | 0.27 | 0.59 | 2.41 | 0.18 | 0.07 |
| Basic: bar after | −7.15* | 0.66 | −2.60 | 3.49** | 0.19 | 0.68 | 3.50** | 0.38 | 0.11 |
| Interpretive | −3.50 | 1.42 | −1.84 | 0.39 | 0.18 | 0.35 | 0.22 | 0.25 | 0.32 |
| Interpretive: bar before | −3.56 | −2.37 | 1.76 | 0.42 | 0.33 | 0.09 | 0.32 | 0.20 | 0.36 |
| Expressive | −2.53 | 3.88 | −3.58 | −0.76 | −0.91 | 0.51 | −0.38 | −0.09 | −0.21 |
| Expressive: bar after | 6.97 | 1.77 | 6.79** | −0.43 | 0.52 | −0.10 | −0.52 | −0.08 | 0.63 |
| Number of notes | 0.98*** | 0.38** | 0.37*** | −0.28*** | −0.06* | −0.05* | −0.16* | −0.03 | −0.02 |
| $R^2$ | .51*** | .38** | .53*** | .42*** | .19 | .28* | .31* | .27* | .16 |

cues may have been used to subdivide the music into expressive phrases, further subdividing the formal sections of the piece. Expressive cues played the same role in the learning of the *Presto* (Chaffin & Imreh, 2002; Chaffin et al., 2002, pp. 213-216). The absence of significant effects for interpretive performance cues suggests that, as with the *Presto,* these cues may have been less important than structural and expressive cues (Chaffin & Imreh, 2002; Chaffin et al., 2002, pp. 215).

#### ALTERNATIVE EXPLANATIONS

Could the effects of basic and expressive performance cues reflect work on technique or interpretation rather than memory retrieval practice, as suggested here? To examine this possibility, the analyses were rerun including all the additional predictors provided by the pianist. These predictors represent the pianist's reports about every aspect of the music that she had thought about during practice. If the effects of basic or expressive performance cues were due to practice of technique or interpretation rather than to memory retrieval, then the effects of performance cues should disappear in the expanded analyses, replaced by the predictors representing more numerous basic or interpretive decisions made during practice.

The effects of performance cues did not disappear; the important effects remained unchanged. Bars before and after basic performance cues were still repeated more in Sessions 4-5 and 6-7. Playing still stopped on bars following expressive performance cues in Sessions 1-3. The extra repetition of these bars was no longer significant and instead of the seven significant effects of performance cues shown in Table 3 there were five. In spite of these changes, the conclusion was the same. It is likely, therefore, that the effects of performance cues described here were due to memorization, not to technique or interpretation. The expanded analyses suggest instead that the pianist had reported her performance cues accurately and that she gave special attention to performance cues during practice in order to establish them as memory retrieval cues. The expanded analyses show that the effects of basic and expressive performance cues that are presented here were robust and not readily open to alternative explanation.

### *Memory Retrieval During Practice Performances*

The pianist expected that her initial attempts to play from memory would be full of hesitations, as she struggled to remember what came next:

> *"By the end of tomorrow's work, I should be able to play it by memory, with stops and bumps and everything."* (Session 1)

"Stops and bumps" appear in the practice graphs as stepwise segments ascending from left to right, representing

**TABLE 4. Regression coefficients (unadjusted) and $R^2$ for effects of the predictors on the tempo of earlier and later mean performances and on the differences between them.**

| | Effects for each mean performance separately Mean Performance | | Effects in later mean performance compared to earlier mean performance Mean performance | |
|---|---|---|---|---|
| Predictor variable | Earlier | Later | Later | $F$ (df = 1,59) |
| Earlier performances | — | — | 0.77 | 11.92*** |
| *Musical structure:* | | | | |
| Beginning of section | 8.67 | −0.94 | −7.58 | 15.29*** |
| End of section | −9.19* | −15.86*** | −8.82 | 10.58** |
| Serial position in section | 0.78 | 1.17* | 0.58 | |
| Switch | −9.74* | −1.93 | 5.53 | 9.79** |
| *Performance cues:* | | | | |
| Basic | −1.32 | 2.23 | 3.24 | 7.63** |
| Basic: bar after | −3.27 | 2.72 | 5.23 | 24.11*** |
| Interpretive | −1.88 | −0.29 | 1.15 | |
| Interpretive: bar before | 0.55 | −0.58 | −1.01 | |
| Expressive | −0.08 | −0.55 | −0.49 | |
| Expressive: bar after | 4.08 | 0.45 | −2.67 | 5.26* |
| Number of notes | 0.13 | 0.29* | 0.19 | 4.95* |
| $R^2$ | .26* | .39*** | .82*** | |

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

interruptions in what would otherwise be long runs through the piece (Figures 3-5). What the practice graphs do not show is whether there were hesitations that did not involve stopping. To find out, we compared the mean bar-to-bar tempi of the earlier practice performances (from Session 4 and the beginning of Session 5) with the mean of the later practice performances (from Session 7 and the end of Session 5) to see if there were hesitations at performance cues in the earlier performances that were not present in the later performances.

The regression coefficients in the left-hand panel of Table 4 represent the effects of the predictor variables on the earlier and later mean performances. Positive values indicate increases, negative values decreases in tempo. For example, the negative effect for switches in the earlier performances indicates that the tempo slowed at switches. Differences between the two sets of performances are shown in the right-hand panel. Column 3 shows regression coefficients for the later performances when tempo in the earlier performances was held constant by including the earlier performances as an additional predictor. These regression coefficients thus represent effects of the predictors remaining after variability present in the earlier performances was removed (Campbell & Kenny, 1999). Differences between performances were evaluated by analyses of variance with predictors as independent variables, tempo as dependent variable, and performances as a repeated measures factor. Differences between performances were indicated by the main effect of performance and its interactions with the other predictors summarized in the column 4 of Table 4.[3]

Tempo slowed at switches in the earlier but not in the later performances (Table 4, columns 1 & 2), suggesting that the pianist hesitated at these points in the earlier performances as she recalled what came next. Switches require information about the upcoming passage to be retrieved from long-term memory so that the correct continuation can be selected. The effect of

[3] Differences were evaluated by analysis of variance in order to provide a single analysis of differences. The regression analysis reported in the right-hand panel of Table 4 represents only one of two possible comparisons. It was also possible to treat earlier performances as the predicted variable and later performances as the additional predictor. Both comparisons are equally valid but do not necessarily yield identical significance levels. The analysis of variance provided a single criterion for evaluating differences. The results are presented in terms of regression coefficients rather than means for consistency with the analysis of practice in Table 2, and because the large number of means involved would be unwieldy.

switches in the earlier performances suggests that, in her initial attempts to play from memory, the pianist hesitated as she struggled to remember the correct continuation. Other effects appear to be due to interpretation. Tempi were slower in the last bars of sections in both sets of performances, a common interpretive device (Clarke, 1995; Krumhansl, 1996). Interpretation is probably also responsible for the other two effects in the later performances. Tempo increased with serial position in a section, suggesting that the pianist delineated each section with a tempo gradient (Gabrielsson, 1999). Tempo was also faster in bars containing more notes, probably because the performer chose to accentuate the increase in musical tension created by the larger number of notes by compressing their delivery.

There were substantial differences between the two mean performances (Table 4, columns 3 & 4). Positive effects in column 3 indicate faster tempi in the later compared to the earlier performances. The positive effect in the top row of column 3 indicates that the later performances were, overall, slightly faster compared to the earlier performances ($M$ = 50.6 and 48.5 beats/min for the earlier and later mean performance respectively). The difference reflects the greater fluency of the later performances. Other positive effects indicate places where the increase in fluency was most pronounced: at switches, basic performance cues, and bars after basic performance cues. We have already suggested that memory retrieval was needed at switches. The similar effect at basic performance cues suggests that they also involved memory retrieval. In the earlier performances, when she was still putting the piece together and learning to play from memory, the pianist hesitated at switches and basic performance cues in order to recall what came next. For basic cues, the effect was so disruptive that it continued into the following bar. In the later performances, in contrast, retrieval from long-term memory had become more automatic; the pianist was polishing for performance, and the hesitations disappeared.

In addition to being more fluent, the later performances also were more expressive. Other differences between the earlier and later performances appear to be due to the development of interpretative gestures. As noted earlier, the increase in tempo in bars with more notes in later performances appears to be a gesture accentuating the added musical tension in these bars. This effect was larger in the later performances. Other differences appear to reflect the increased use of tempo to delineate sections and expressive phrases. At the ends of sections, slowing already present in the earlier performances increased, and at the beginnings of sections a small increase in tempo in the earlier performances became a small decrease in tempo in later performances. The same change occurred in bars following expressive cues, further supporting the conclusion suggested by the practice data that the pianist divided the piece into expressive phrases that started in these bars (Sloboda & Lehmann, 2001).[4]

#### ALTERNATIVE EXPLANATIONS

To examine the possibility that the effects of switches and basic performance cues could reflect effects of technique or interpretation rather than memory retrieval, as suggested here, the analyses were rerun including all of the additional predictors provided by the pianist. The results of expanded analyses suggest that the effects were not due to other properties of the music. The important effects of basic performance cues and switches were the same. Their effects were not, therefore, due to technique or interpretation. It is likely that the slowing at these points in the earlier performances was due to the need to remember what to do and that these hesitations decreased in later performances as memory retrieval became more fluent.

### *Comments About Memory*

The most frequent topic of the pianist's comments in every session was memory, probably because it was the subject of the research and also because she had few problems with technique or interpretation. The following comment from the beginning of Session 1 shows that memorization was one of the pianist's main goals from the outset:

> "*That's the first phrase [the A theme]. I'm trying very much to learn it—memorize it—right away, because it is possible to memorize instantly. For instance, I remember the fingering I use and the notes here. I remember I have to change, [and] change again.*" (Session 1)

Because memorization was salient to the pianist, her comments provide many examples to illustrate the three principles of expert memory. The comments are, of course, evidence of the pianist's beliefs about memory, not of memory processes. They do, however, provide a qualitative picture of her memorization strategies, about which she had very definite ideas. At the time, she had no

[4] The absence of effects of interpretive performance cues probably reflects the fact that some interpretative gestures involved decreases, and others increases in tempo, resulting in no overall effect.

knowledge of the theories of expert memory described in this article and had not yet articulated for herself the idea that she used performance cues (see Chaffin et al., 2002, pp. 250-254). Nor did the pianist know that she would later be asked to provide the reports about the music used as predictors in the analyses above.

### FAMILIAR PATTERNS

Although the behavioral data provide no evidence about the first principle of expert memory—that building blocks of memory are familiar patterns already stored in memory—the pianist made many comments in the early sessions about her search for patterns to aid memorization, and departures from expected patterns that had to be remembered:

> "*The reason this is easy to remember is, there's one harmonic structure, which ends on a strange D, so we save [having to memorize] most of the chords, and [acoustic memory for] the melody will handle [the D]*". (Session 1)

Identifying patterns is, of course, an active process. Some patterns, such as the latent polyphonic organization of the score, were far from obvious:

> "*I have this very strange way of memorizing. I don't understand it myself. I memorize things in blocks [soprano, tenor, and bass voices]. For instance, I cannot relate the [notes of the] left hand bass [voice] . . . to anything but themselves. I see them in a sequence, and try to see each [voice] continue.*" (Session 1)

Other patterns were created by the pianist by choice of fingering:

> *"Okay, I can put these four [notes] in a sequence . . . It [the sequence] helps to memorize a lot.*" (Session 1)

Using consistent fingerings when a pattern of notes repeated reduced the memory work:

> "*There's two different fingerings for it . . . I'm trying to see if I can do one [fingering] for both . . . I think I can.*" (Session 2)

Even so, fingering was one of the main things that had to be remembered:

> *"For now, it's little fingering glitches that make you get through a passage or not . . . It's all up to how you put your hands [on the keyboard].*" (Session 1)

Relying on similarities of fingering to help memory made it particularly important to remember the differences:

> "*I didn't remember to change the fingering for the second repetition.*" (Session 1)

Differences like these often became basic performance cues, requiring attention during performance to ensure that they were executed as planned, and this is the closest the pianist came to explicitly mentioning the topic of performance cues.

Like most musicians, the pianist did not consider her search for patterns of various sorts to be "memorization" (Chaffin et al., 2002, Ch. 3):

> "*I'm not even looking at memory yet. I'm just trying to see how things fit. I'm picking up things all the time that I think are important for memory. Right now [it] seems more like learning than memorizing . . . I imagine by the end of another session like that . . . I should be able to know enough about it that I can get through it.*" (Session 1)

### RETRIEVAL ORGANIZATION

The largest scale patterns of a piece are the melodic themes and sub-themes of the formal structure that provide the musician with a ready-made retrieval organization. The pianist actively sought out these landmarks, comparing different passages to identify similarities and differences:

> "*That's the first phrase [theme] . . . and this is again the same [theme]. We are not having parallel melodies [in the two repetitions of the same theme]. It's a D flat [the first time], and the second time it just . . .*" (Session 1)

As she began work on the *B* theme in session 2, the pianist described what she was looking for:

> *"So, I'm going to try to run it . . . fast a few times, just to try to catch the big blocks [sub-sections of the B theme].*" (Session 2)

Once identified, the different sub-sections were compared:

> "*I'm trying to compare the two starts [of subsections of the B theme] . . . [in] bars 27 and 31.*" (Session 2)

Similarly:

> "*I'm going to try to compare the two [right] hands. . .*" (Session 3)

The pianist also used the formal structure to refer to particular passages:

> "*I'm trying to run through the middle section [Aa2] for the fourth time . . .*" (Session 6)

**TABLE 5. Rate/Tempo ratio data across the two-week learning period.**

| | Stage | | | | | | |
|---|---|---|---|---|---|---|---|
| | Section-by-section | | | Putting-together | | Polishing | |
| Descriptive statistic | Session 1 | Session 2 | Session 3 | Session 4 | Session 5 | Session 6 | Session 7 |
| Mean target tempo (beats/min.) | 63 | 62 | 58 | 55 | 57 | 52 | 48 |
| Practice rate (beats/min.) | 37 | 42 | 43 | 39 | 44 | 39 | 40 |
| Rate/tempo ratio | 0.59 | 0.67 | 0.74 | 0.71 | 0.77 | 0.75 | 0.83 |

### RETRIEVAL PRACTICE

The pianist began trying to play from memory almost immediately. Early in Session 1, she commented:

> "*Okay, I have to remember this . . . . [plays] As you see, I am trying to play as much as possible from memory . . .*" (Session 1)

The effort put into retrieval practice was striking. For example, after struggling through the first two pages from memory, she remarked:

> "*Anyway, I'm trying to muddle through without music just to see what I remember. Actually from the whole [first] page there was one place where I could not continue, and maybe I wasn't concentrating hard enough, because probably, given enough time, I could have gotten through it.*" (Session 2)

As she played from memory, she listened for mistakes and later checked them in the score:

> "*I made mistakes and actually I knew [what I was doing wrong] as I was playing . . . So what I'm going to do is go through it a couple of times and really look at the music.*" (Session 2)

> "*I almost skipped a bar at measure 17. I wanted to check bar 35, because I think I did leave out [the] bottom note.*" (Session 4)

> *"Every time you look at it for a while from now [on], there's going to be something else that is going to resurface . . . that hasn't been consciously memorized yet and put into cognitive [declarative] memory . . . Once in a while I play with the music just to check things. There's always a little detail that escapes.*" (Session 5)

She constantly evaluated her progress:

> "*Basically, I wanted to check what I could remember from yesterday, and it looks like the first page stuck pretty well, and a few things from the second page.*" (Session 2)

> "*I still made a few mistakes, but not too many.*" (Session 4)

> *"OK, I made a couple of mistakes.*" (Session 7)

### *The Rate/Tempo Ratio as a Measure of Retrieval Practice*

The pianist's comments suggest that she was constantly testing her memory, "muddling through" even when the notes did not come easily. The hesitations at switches and basic performance cues during the early practice performances (Table 4 above) confirm that she hesitated during these early performances. The presence of similar hesitations in practice more generally is suggested by the rate/tempo ratios shown in Table 5. The rate/tempo ratio (described in the Procedure) provides a measure of the prevalence of hesitations over entire practice sessions by comparing the mean target tempo at which the pianist was trying to play during a session with the practice rate at which she actually played. The rate/tempo ratio is the discrepancy between these two measures and provides an indication of the proportion of practice time spent in short pauses, usually no more than a few seconds, and momentary decreases in tempo. The rate/tempo ratio thus provides a global measure of the time devoted to thinking rather than playing during practice. In the present case, the pianist's comments indicate that she was thinking a lot about memorization; therefore, the rate/tempo ratio provides a measure of the time spent thinking about memorization, along with other issues.

The rate/tempo ratio increased across sessions from .59 to .83, with a mean of .72.[5] To give a sense of what a

[5]Table 4 also shows that the mean target tempo decreased across sessions. The change probably reflects the pianist's increasing focus on musical expression. As she explained in the following observation about her first public performance: "*I probably played it a little bit slower [than in practice], and I enjoyed more to slow down here and there, just to try to give the right mood, which, when you practice and you just fix things... or you just don't feel like it.*" For this reason, the faster tempi in the later performances in Table 4 were probably due to an increase in fluency rather in expressivity.

ratio of .72 means, if the pianist had kept to her target tempo throughout, she would have finished in 3½ hours instead of practicing for nearly 5 hours. Alternatively, if she had practiced the same amount of time, she could have played half as much music again. The rate/tempo ratio thus substantiates the impression given by the pianist's comments that she worked very hard to play from memory throughout each practice session. By "muddling through," she practiced memory retrieval.

## Conclusions

The main goal of the study was to see whether the pianist would engage in extended retrieval practice, as predicted by the third principle of expert memory (Chaffin & Imreh, 2002; Ericsson & Kintsch, 1995; Williamon & Valentine, 2002). The answer was clear; the time and effort put into practicing memory retrieval was the most striking feature of the learning process. Even in the limited two-week time frame within which the pianist learned *Clair de Lune,* there was abundant evidence of retrieval practice: in the starts and stops during practice, in the hesitations during practice performances, in the pianist's comments, and in the rate/tempo ratio. The pianist saw memorization as her main challenge and actively worked at it from the outset.

Like expert memorists in other fields, the pianist engaged in extended retrieval practice in order to be able to play without interruptions or hesitations. Although the learning of *Clair de Lune* took place in two weeks while the *Presto* took the same pianist 10 months (Chaffin et al., 2002), the learning process for the two pieces was very similar. An initial sight-reading through the piece to get the big picture was followed by sessions of section-by-section practice, putting the piece together to play from memory, and polishing for performance. In each stage, the pianist practiced performance cues, attending to different cues at different points. This conclusion is consistent with that of other longitudinal case studies involving both prolonged practice (Chaffin et al., 2006) and shorter periods of practice, (Ginsborg et al., 2006; Noice, et al., in press).

The most important behavioral evidence of retrieval practice was the attention given to basic performance cues. The idea that experienced musicians use performance cues to monitor and guide their performances emerged from the study of the *Presto* (Chaffin et al., 2002). Musicians attend to features of the music during practice and thus establish them as retrieval cues. During performance these cues automatically elicit the motor and auditory memories of what comes next and the declarative memory needed to monitor and guide playing. These performance cues provide a necessary safety net for the professional performer, allowing recovery from mishaps and memory lapses.

The pianist practiced basic performance cues in sessions 4-5, when she was putting the piece together to play from memory, and in sessions 6-7, when polishing for performance. In both stages, she repeated bars containing basic performance cues, and the bars after them, more than other bars. The effect of this repetition was evident in the bar-to-bar tempo of practice performances in these sessions. The early practice performances in Sessions 4-5 were marked by hesitations at basic performance cues and switches. The later practice performances, in contrast, were more fluent at these points. Basic cues and switches are places where we expect retrieval from long-term memory to take place. The increasing fluency of the performances at these points shows that the repetition during practice increased the speed and automaticity of retrieval.

The pianist's comments supported the behavioral evidence that the pianist was practicing retrieval by making it clear that she saw memorization as the main challenge in learning the piece and actively worked at it from early in Session 1. The rate/tempo ratio further supported this conclusion by showing that the pianist spent more than a quarter of the time that she was playing in pauses for thought. The analyses of practice and tempo suggest that a great deal of this additional time was spent thinking about basic performance cues.

There was also ample evidence for the second principle of expert memory, the use of a well-learned retrieval organization (Ericsson & Kintsch, 1995). The pianist used the formal structure of *Clair de Lune* as a framework for practice, showing that she was thinking about the music in terms of its structure. In Sessions 1-3, practice took place section-by-section. At the same time, in these and in the other sessions, the pianist used section boundaries as starting places, as well as using them as stopping places in Sessions 1-3. While this pattern of practice does not directly show that she was using the formal structure as a retrieval organization, it does show that she was constantly thinking about the formal structure as she practiced. Similar use of musical structure to organize practice has been observed in other studies of experienced musicians (Chaffin & Imreh, 2002; Miklaszewski, 1989; Williamon & Valentine, 2002).

Expressive phrases provided another layer to the hierarchical organization of the piece into sections and subsections. The pianist used expressive cues as starting places early in practice, showing that she was already thinking of the music in terms of expressive phrases

during the initial practice sessions (Chaffin et al., 2002, pp. 189-190, 199-200; Chaffin et al., 2003). In Sessions 1-3, she repeated more and stopped more at bars at the beginnings of expressive phrases (i.e., bars after expressive cues), just like bars at the beginnings of sections. The pianist continued to think of the piece in terms of expressive phrases in the later sessions, using tempo to mark the beginnings of expressive phrases in later practice performances. This musical gesture was the same one used to mark the beginnings of sections.

Support for the first principle of expert memory, the use of familiar patterns to encode the music, was more limited (Ericsson & Kintsch, 1995). The first principle was supported by the pianist's comments in Sessions 1-3, showing that her search for patterns was a deliberate strategy that she believed helped her to memorize. Unlike the *Presto* study (Chaffin et al., 2002), however, the behavioral data from these sessions did not provide confirming evidence. Practice was not affected by the number of familiar patterns in a bar, perhaps because the pianist found the patterns in Debussy's music easier to integrate than those in Bach's.

This study of *Clair de Lune* has shown that the principles of expert memory that accounted for the memorization of the *Presto* apply equally well to the learning of another piece in a very different musical style over a much shorter time span. The same principles of expert musical memory have also been shown, in other studies cited earlier, to apply to other soloists, instruments, and musical traditions. Generalization from these case studies is based on support for general psychological principles (Ericsson & Oliver, 1988). Musicians' use of musical structure and performance is consistent with principles of expert memory developed from the study of experts in other fields and with principles of memory derived from the study of the general population. There is good reason to expect, therefore, that the same principles generalize to most experienced performers.

## Author Note

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