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"Seeing the Big Picture": Piano Practice as Expert Problem Solving

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Experts in many fields approach a new problem by identifying the general principles involved before starting work on details. Do expert musicians similarly begin work on a new piece with the big picture, an artistic image of the piece, in mind? To find out, a concert pianist recorded her practice of the third movement, *Presto*, of J. S. Bach's *Italian Concerto*, commenting as she did so about what she was doing. The behavioral record of where playing started, stopped, and slowed down indicated the musical dimensions affecting practice, while the comments indicated the main focus of the pianist's attention. An artistic image for the piece was already evident in the initial sight-read performance, guided work on technique in sessions 1–6, and was transformed into a plan for performance by practice of performance cues in sessions 7–8. Interpretive details were added in sessions 9–10 and remaining problems touched up in session 11–12. Despite its pervasive effects on practice, the pianist's artistic image was mentioned only indirectly in comments about technique in sessions 1–6 and about structure, memory, and interpretation in later sessions.

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How do musicians deal with the competing demands on their attention when first learning to play a new piece? On the one hand, decisions about technique cannot be ignored; fingerings must be selected and solutions for technical problems must be found just to play the notes. At the same time,

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the best solutions to many problems of technique depend on interpretive decisions. So unless the musician begins with a clear idea of the "big picture," or overall musical shape of the piece, fingerings and other basic motor skills are likely to need relearning once the interpretive decisions have been made. The noted pianist and pedagogue Heinrich Neuhaus suggested that, when acquainting themselves with a new piece, musicians need to form an "artistic image" of the piece and that with a great musician "an instantaneous and subconscious process of 'work at the artistic image' takes place" (Neuhaus, 1973, p. 17).

Interviews with eminent musicians suggest that they do indeed begin by forming an artistic image of a new piece. Wicinski (1950, reported in Miklaszewski, 1989) interviewed 10 eminent Russian pianists, including Neuhaus and his pupils Sviatoslav Richter and Emil Gilels, about how they went about learning a new piece. Seven of the pianists reported that their preparation went through distinct stages. They began by getting to know the piece and developing preliminary ideas about how the work should be performed, that is, by developing an artistic image. Next they worked on technical problems. Finally, they returned to the larger musical picture with practice performances. Accomplished musicians of other sorts also report beginning work on a new piece by getting an overall idea of structure, tempo, and technical problems (Hallam, 1995a, 1995b). As one musician put it, "Probably, I'll play straight through initially, to get a feel for the piece in its entirety, particularly tempo and generally how it should go (Hallam, 1995a, p. 118)."

These accounts are suggestive, but retrospective reports are notoriously unreliable (Nisbett & Wilson, 1977; Ericsson & Simon, 1980), and in this case also leave open questions about how attention is divided between the artistic image and the technique necessary to realize it. To learn more about how an experienced performer approaches a new piece, we observed a concert pianist (the second author) learning the third movement, *Presto,* of the *Italian Concerto* by J. S. Bach. The pianist videotaped her practice, commenting periodically about what she was doing. We focus here on the initial learning of the piece in Sessions 1–12.

We have described aspects of these data elsewhere (Chaffin & Imreh, 1997, 2001, 2002; Chaffin, Imreh, & Crawford, 2002; Imreh & Chaffin, 1996/1997). The present inquiry differs from earlier reports in three ways. First, the main focus of earlier reports was on memorization, whereas here our goal is to understand how attention is allocated between the big musical picture and details of technique. Second, we examine the initial sight-reading of the piece, data not reported before. Third, we describe how practice changed from session to session rather than combining data across sessions (Chaffin & Imreh, 2001, 2002), and we report the data fully rather than in summary form as in Chaffin et al. (2002, Table 8.4).

There is much to be learned from studying expert practice. Despite a justifiable preference in psychology for studying simple paradigms, principles developed from the study of simple skills do not always generalize to more complex situations (Wulf & Shea, 2002). Case studies, like the present inquiry, are an appropriate tool for studying experts. The skills required for a career as a concert soloist in the Western classical tradition take 10–20 years of dedicated training to develop, substantially modifying physical and mental capabilities (Ericsson, Krampe, & Tesch-Römer, 1993). Such training increases the normal range of individual differences so that aggregating observations across individuals runs the risk of obscuring phenomena of interest. Generalization from the study of exceptional cases must be based on the identification of the psychological processes involved with those reported in other studies. For example, Chaffin and Imreh (2002) argue that principles of expert memory (Ericsson & Kintsch, 1995) account for how the pianist in our study memorized, even though those principles were based on the study of very different kinds of skill.

Learning a New Piece As Expert Problem Solving

In the present inquiry, we ask whether principles of expert problem solving developed in other domains apply to concert pianists. The task of learning a new piece of music can be seen as a complex problem-solving task. Two principles of expert problem solving appear particularly relevant. First, Neuhaus's (1973) dictum that great musicians immediately grasp the artistic image of a new piece is reminiscent of reports that experts in fields like physics and mathematics approach new problems by identifying the underlying principles involved and understanding the broad scope of the problem. If these are not immediately evident, they take the time to develop a deeper understanding. Novices, in contrast, tend to focus on superficial characteristics, plunging into the details without developing a clear idea of the big picture (Glaser & Chi, 1988; Chi, Feltovich & Glaser, 1981; Lesgold, Rubinson, Feltovich, Glaser, Klopfer, & Wang, 1988; Paige & Simon, 1966; Schoenfeld & Herrmann, 1982; Weiser & Sheertz, 1983). If forming an artistic image of a piece before starting work on technique is akin to identifying the underlying principles involved, then expert musicians appear to approach the learning of a new piece in much the same way that experts in other domains approach new problems, by starting with the big picture.

Second, Neuhaus's (1973) suggestion that great musicians' grasp of the artistic image of a piece is "instantaneous" and "unconscious" is reminiscent of the ability of experts in other domains to make decisions intuitively and immediately without having to think things through. For example, chess experts are able to maintain a high level of play while playing "speed"

chess with only a few seconds for each move and no time to review alternatives or think through consequences (Chase, 1983; Glaser & Chi, 1988; Gobet & Simon, 1996). Less accomplished players, who are able to play a respectable game when given more time, rapidly fall apart under speed rules. Experts are able to make snap decisions about what to do by recognizing the similarity of the current situation to ones encountered in the past (Anderson, 1995, chap. 8; Chase, 1983; Gobet & Simon, 1996). It seems likely that the "instantaneous and subconscious" problem solving described by Neuhaus (1973) is the result of a similar process. When first sight-reading through a new piece, familiarity with the style, composer, and earlier performances of the same piece would allow an expert pianist to make snap decisions that would anticipate those made later in practice with more time for reflection.

Automatic Versus Deliberate Problem Solving During Practice

How well do these two principles describe the way that the pianist in the present study approached the learning of the *Presto*? Like other complex activities, piano playing and practice are organized by goals and subgoals in action hierarchies (Carver & Scheier, 1998; Rosenbaum, 1987). Attention moves up and down the hierarchy, focusing sometimes on higher and sometimes on lower level goals (Williamon, Valentine, & Valentine, 2002). The same action can be labeled differently depending on the level at which it is described, for example, "use the first finger for the F," "bring out the theme," "a rousing conclusion." Reports of ongoing behavior thus reflect the level in the action hierarchy that is the current focus of attention (Carlson, 1997; Vallacher & Wegner, 1987). In contrast, practice, with its rapid starts, stops, and repetitions, is a product of all the levels in the action hierarchy. For example, recognizing a hidden polyphonic theme in a score, a musician may automatically start to articulate the notes of the theme even while deliberating about what fingering to use. Both decisions will be reflected in the way the passage is practiced, but only the decision that was the focus of conscious deliberation will be mentioned when the pianist describes what she is doing. By comparing activity at the keyboard with the pianist's comments we may, therefore, be able to distinguish those aspects of the music that were handled more automatically and intuitively from those that were dealt with more deliberately.

Analyzing the Microstructure of Practice

The strategy we have outlined requires a method for analyzing both the pianist's comments and the microstructure of practice (Chaffin & Imreh,

2001; Chaffin et al., 2002, chap. 8). Comments directly express the topic the musician is thinking about and can be quantified by content analysis (e.g., Chaffin et al., 2002, chap. 7; Gruson, 1988; Miklaszewski, 1989). For practice, the object of a musician's attention is revealed by the choice of where to start and stop, what to repeat, and by the location of hesitations. The behavioral record of these events can be laid alongside the musical score to see how the complexity of the music affected practice. For example, when practice consistently starts or stops or repeats at section boundaries, we infer the musician was attending to the formal structure.

Besides the formal structure, the aspects of a piece of music that require attention during practice are of three main types. Three basic dimensions require attention simply in order to play the notes (fingering, technical difficulties, and familiar patterns of notes). Four interpretive dimensions provide musical shape to the notes (phrasing, dynamics, tempo, and pedal). Three performance dimensions represent the cues the pianist attends to during performance (basic, interpretive, and expressive performance cues; see Table 1 for a summary; for more details see Chaffin & Imreh, 2001; Chaffin et al., 2002, pp. 166–171). Other classifications and categories are clearly possible, but this scheme has proved adequate for the present inquiry.

The idea behind the basic and interpretive dimensions will be familiar to anyone who has played a musical instrument. The performance dimensions, on the other hand, are more novel and require some explanation. Implementation of decisions about basic and interpretive dimensions be-

TABLE 1
Dimensions of a Composition That a Pianist Must Attend to and Make Decisions About While Learning and Performing

Basic dimensions: require attention simply to play the notes
Familiar patterns—such as scales, arpeggios, chords, rhythms
Fingerings—decisions about unusual fingerings
Technical difficulties—places requiring attention to motor skills (e.g., jumps)
Interpretive dimensions: shape the musical character of a piece
Phrasing—grouping of notes that form musical units
Dynamics—variations in loudness
Tempo—variations in speed
Pedal—use of pedal
Performance dimensions: require conscious attention in performance
Basic cues—familiar patterns, fingering, and technical difficulties
Interpretive cues—phrasing, dynamics, tempo, pedal
Expressive cues—emotion to be conveyed, such as surprise
Formal Structure: divides a piece into sections based on thematic content
Section boundaries—beginnings and ends of sections and subsections
Switches—places where two (or more) repetitions of a theme diverge

comes automatic with practice, allowing the pianist to decide which features to pay attention to while performing. With practice, attention to these features becomes automatic so that they come effortlessly to mind as the piece unfolds, becoming performance cues. These cues provide a means of consciously anticipating and directing the highly practiced, automatic movements of hands and fingers. Basic and interpretive performance cues are subsets of the basic and interpretive features, that is, those features selected for attention during performance, whereas expressive performance cues represent the musical turning points—the changing emotions—that the performer wants to draw to the audience's attention. Expressive cues are a distillation of the musical effects of all of the other dimensions, representing the ebb and flow of feeling produced by the musical structure.

The detailed description of the music required for this analysis was provided by the pianist, who reported all the features and cues that she had paid attention to at any point during the learning process by marking them on copies of the score (Chaffin & Imreh, 2001, 2002; Chaffin et al., 2002, pp. 171–173). A count of the number of features or cues in each bar provided a measure of the complexity of the bar on that dimension. In addition, the pianist identified the critical locations in the formal structure: boundaries between sections and subsections (called collectively "sections" below) and the location of switches, places where identical repetitions of the same theme first begin to diverge from each other (see Chaffin et al., 2002, pp. 95–96 for an example).

These measures of musical complexity and structure then served as predictor variables in regression analyses in which the dependent measures were the number of starts, stops, and repetitions and the duration of each bar. If the pianist hesitated at features of a particular dimension, or started, or stopped or repeated those bars more than other locations, this would indicate that the pianist was paying special attention to that dimension (Chaffin & Imreh, 2001; 2002; Chaffin et al., 2002, chap. 8). The analyses thus provided a way of validating the features and cues reported by the pianist and also allowed identification of the dimensions affecting practice at each stage of the learning process.

Effects of the Artistic Image on Practice and Comments

How can the measures we have described be used to decide whether a pianist has an artistic image of a new piece in mind during practice or not? An artistic image might be reflected in attention to structure, performance cues, or interpretation. If playing is affected by the formal structure, this suggests that the big musical picture of how the piece is organized by sections is influencing what the pianist does. If playing is affected by perfor-

mance cues, this indicates that the pianist has a plan for performing the piece and is singling out for special treatment the cues that will be used to guide the polished performance. If practice is affected by the interpretive dimensions, this indicates that the pianist has made some of the interpretive decisions needed to implement her artistic image (Sloboda & Lehmann, 2001). Likewise, comments about any of these topics indicate that they are the focus of the pianist's problem-solving efforts.

We have previously reported that the pianist in the present study selectively used section boundaries as starting and stopping places and that she did this more in the initial sessions than later in the learning process (Chaffin & Imreh, 1997; Chaffin et al., 2002, chap. 9). This use of the formal structure early on in practice suggests that the pianist already had the big musical pictures in mind during the initial sessions. This conclusion is supported by the fact that student pianists do not use the formal structure in the same way until later in the learning process. Use of the formal structure to organize practice begins earlier for more experienced students and is associated with more musical final performances (Williamon & Valentine, 2000, 2002). Advanced students appear to be more like the pianist in our study, using the formal structure to organize practice from the start (Miklaszewski, 1989; Nielsen, 1999, 2001). The selection of starting places during practice thus appears to reflect the level of the performer's understanding of a piece. Musicians start at section boundaries because they recognize their musical significance and students who recognize these points earlier in their learning of a new piece are better able to prepare a convincing interpretation. The early use of the formal structure by the pianist in the present study thus provides one suggestion that she had formed an artistic image of the piece early on.

Predictions

The development of an artistic image should be reflected in effects on practice of the formal structure, the performance dimensions that represent the pianist's ideas of how the work should be performed, and the interpretive dimensions that provide musical shape to the notes. Work on technique should be reflected in effects of the basic dimensions (fingering, technical difficulties, and familiar patterns of notes). If Wicinksi (1950, cited in Miklaszewski, 1989) is correct and an initial survey of the big picture is followed by a stage of working on technique, then we would expect to see initial effects of structural, performance, and interpretive dimensions on practice, followed later by effects of basic dimensions. On the other hand, if decisions about technique are made first, before the formation of an artistic image, then we would expect to find the basic dimensions

affecting practice in earlier sessions and effects of structural, performance, and interpretive dimensions appearing later.

If Neuhaus (1973) is correct and the development of the artistic image is "instantaneous and subconscious," then we would expect to find it affecting practice early in the learning process without being explicitly mentioned in the comments. This would suggest that the development of the artistic image was the product of the kind of rapid, intuitive decision making that is characteristic of other kinds of experts when they perform under time pressure (e.g., Gobet & Simon, 1996). On the other hand, if achieving an artistic image for the piece required deliberate effort, then we would expect to find comments about those efforts in addition to effects on practice. For example, the pianist might talk about the differences between the different sections, or describe the musical feelings that she was trying to achieve.

Method

THE PIANIST

Gabriela Imreh was trained as a concert pianist in Romania. During the 10-month period covered by this study, she gave about 30 concerts involving two different recital programs, and performed 5 concerts with orchestra, in addition to preparing the program that included the piece selected for study.

THE MUSIC

The third movement, *Presto,* of the *Italian Concerto* by J. S. Bach was learned for the professional recording of an all-Bach CD (Imreh, 1996). The pianist had played Bach throughout her career and had taught the *Italian Concerto* to a student 3 years before the start of the present study, but had not played the piece herself. The *Presto* is of moderate difficulty (Hinson, 1987), is scored in 210 bars, is divided into 16 main sections and 37 sub-sections, is notated in 2/4 time, and lasts for 3–4 minutes at performance tempo.

PROCEDURE

Practice Sessions

The pianist videotaped her practice from the first time she sat down at the piano until she performed the piece without the score at the recording session. Here we report data for 12 practice sessions totaling 11 hours and 19 minutes. To simplify description, data for adjacent sessions were combined into four sets, sessions 1–6, 7–8, 9–10, and 11–12. The grouping was based on an inspection of the data for individual sessions, which indicated that results for sessions in the same set were similar.

Tempo Variation During Sight-reading

Variations in tempo during the initial sight-reading of the piece at the beginning of the first session were examined by measuring interbar intervals (IBIs) with a commercial soundwave-processing program. Independent remeasurement of 10 bars indicated that all of the measurements were accurate within 30 ms and the mean difference was 15 ms.

Comments

The pianist commented on what she was doing as she practiced, pausing briefly to do so. Her comments were transcribed and classified into the 20 topics listed in Table 2. The topics were organized, in turn, into four broad groupings, allowing each comment to be classified as concerned with basic issues (fingering, technical difficulties, and familiar patterns), interpretation issues (phrasing, dynamics, tempo, and use of pedal), or performance issues (memory, attention, musical structure, and use of the score). The remaining topics concerned metacognitive issues, such as self-evaluation and descriptions of plans and strategies. Comments from all sessions were independently classified by two judges with an agreement rate of 86.8% (kappa = .78) across all practice sessions.

Measuring Amount of Practice

Practice was transcribed by recording the bar on which each practice segment started and stopped. A practice segment was considered to be any continuous playing of the score. Practice segments were classified either as runs (the playing of longer passages) or as work (the repetition of the same short passage). A run was defined as a practice segment or sequence of segments that covered more than two complete sections of the piece. Any prac-

TABLE 2
Categories Used in Content Analysis of Comments During Practice

Basic Dimensions	
Fingering	"Here I change the fingerings to be perfectly symmetrical."
Technical	"It sounds absolutely insane because of the large stretch."
Patterns	"I need so many [fingerings] written in because the music is . . . unpredictable . . . less patterns."
Interpretive Dimensions	
Phrasing	"I'm trying to phrase similar notes differently."
Tempo	"At least there's no tempo problems."
Dynamics/Pedal	"I was thinking about bringing out all the long notes."
Interpretation	"It's really a polyphonic theme . . . not theme and accompaniment."
Performance-Related Topics	
Memory	"I'll . . . see where the holes in memory are."
Musical structure	"Probably now the seams are quite obvious. . . . I have to check each transition because every time it's something different."
Use of score	"Okay, I suppose we can put the music away."
Attention	"As soon as my concentration goes, you can hear it."
Metacognitive Topics	
Plans + strategy	"I still have tons of work, but . . . let's just call it a rough draft."
Slow practice	"I am going to play it . . . definitely under tempo."
Metronome	"The metronome seems to have helped."
Learning process	"When you come back after a few days of not playing . . . you do have a fresh idea."
Research process	"It's a little bit inconvenient to turn the machine on."
Fatigue	"I'm going to stop because I am very tired."
Evaluation	"Well, the first two pages are . . . starting to sound a little better."
Affect	"Aagh, it's torture!"
Editor	"I am going to look at another edition, because I want to know if I have options."

tice segment that was not part of a run was classified as work. Shorter segments were counted as part of a run if the pianist appeared to be trying to play a segment of two or more sections even if it was interrupted by the need to correct a few notes (see Chaffin & Imreh, 2001, for details). For each session, the number of repetitions, starts, and stops for each bar were counted and tabulated separately for runs and work.

Measures of Musical Complexity and Structure

The pianist marked the features for each of the dimensions in Table 1 on copies of the score. This was done separately for each dimension at the end of the project while the pianist was listening to tapes of the recording session. Reporting occurred earlier for sections and switches (after Session 12), and for Section C (after Session 31; see Chaffin & Imreh, 2001, and Chaffin et al., 2002, chap. 8 for details).

The musical complexity of each bar was measured for each of the 10 dimensions by counting the number of features or cues reported for each bar. Location in the formal structure was represented by four measures. First bar in the section and last bar in the section were represented by dichotomous dummy variables. Serial position in a section was numbered consecutively from the beginning of the section. Switches were represented by counting the number of switches reported for each bar. For the analysis of IBIs, theme (A,B,C, or D) was included as a predictor by coding the bars of each theme with a dummy variable reflecting the rank ordering of the mean IBI for the different themes from fastest (1) to slowest (4) in the final performance recorded on the CD. Number of notes in a bar was also included as a predictor in all analyses.

Regression Analysis

To determine which dimensions affected practice, multiple regression was used to relate the complexity and structural features of each bar to how much it was practiced and how fluently it was played in the initial scouting run. Dependent variables were log-transformed IBIs for the scouting run and the number of starts, stops, and repetitions of each bar in the first 12 practice sessions. Predictor variables used in all analyses were the musical complexity on each of the 10 dimensions, the measures of location in the formal structure, and number of notes per bar. All predictor variables were simultaneously entered into the regression.

On the basis of preliminary analyses, the three variables representing location in a section (beginning, end, and serial position in a section) were based on major section boundaries for analyses of IBIs and on subsection boundaries for analyses of starts, stops, and repetitions. The first bar of the piece was omitted from analyses of starts, the last bar was omitted from analyses of stops, and the last three bars were omitted from the analysis of IBIs.

Results and Discussion

STAGES OF THE LEARNING PROCESS

The preparation of the *Presto* took place in 57 sessions totaling 33.5 hours over 39 weeks. Practice sessions were grouped into three main periods separated by intervals of up to 3 months during which the piece was not played. The first learning period consisted of 12 sessions totaling nearly 12 hours over 5 weeks (see Chaffin & Imreh, 2001, 2002, and Chaffin et al., 2002 for the later periods).

Practice during the first learning period can be divided into four phases: scouting-it-out, section-by-section, the gray stage, and maintenance. Scouting consisted of sight-reading slowly through the entire concerto at the beginning of Session 1. This was immediately followed by section-by-section practice in which the pianist went through the piece a few sections at a time making fingering decisions and establishing motor memory through repetition. This continued through Session 6, at which point there was a 3-day break during which the pianist worked on the first movement. When she returned to the *Presto* in Session 7, a new stage began with work in each session ranging over the entire piece, rather than being limited to a few sections as before. The goal was to develop the ability to play through the whole piece fluently. This was achieved for the first time at the end of Session 8, which ended with five fluent runs through the whole piece, one of which was "mostly from memory." We call this the "gray" stage because playing no longer had to be consciously directed all the time but was not yet completely automatic. Gray stage practice continued through Session 10, which coincided with the New Year. The pianist had set herself the goal of completing the initial learning of the piece by this date and, although there were two more sessions after this point, the character of practice changed. As the pianist noted at the beginning of Session 11, her goal was now "just running through the concerto… and fix[ing] whatever goes wrong." Two final sessions of this kind of maintenance practice marked the end of the first learning period. At the end of Session 12, the pianist noted that the piece was "60% done" and played it twice through from memory before setting it aside for 3 months.

We will examine each stage in turn, asking to what extent practice was directed by structural, performance, basic, and interpretive considerations. We will see that scouting-it-out appears to correspond well to Wicinski's (1950, cited in Miklaszewski, 1989) first stage of developing preliminary ideas for performance, and section-by-section practice appears to correspond with his second stage of work on technical problems. Wicinski's third and final stage of practice performances was not reached until Session 17 (Chaffin et al., 2002, pp. 107–109), but gray stage practice can be seen as a transition during which practice performances are the goal but work on technique is still needed. The stages of the learning process observed thus correspond with, but are more detailed than, those identified by Wicinski.

INTERBAR INTERVALS DURING SIGHT-READING

The initial sight-reading run through the piece was done at a slow tempo with many fluctuations and hesitations, but without ever coming to a complete stop and without repeating anything. The pianist reported in a later interview that her goal was not a fluent performance, but to "scout-it-

out." She needed to identify the repetitions and variations of the different themes and was looking for ways to make the music interesting by making each return of a theme distinctive.

There were no comments or stops and starts during the initial sight-reading and so the only measure available to test this account was the tempo, which frequently slowed as the pianist thought about what she was doing or looked ahead. The location of these hesitations provide an indication of which dimensions the pianist was attending to. The scouting run for the *Presto* took 10 min 8 s, with IBIs ranging from 1.4 to 10.8 s with a median of 2.6 s. This was far from both the *presto* tempo called for in the score and used in the eventual performance for which the median IBI was 0.8 s.

The regression analyses show us what caused the hesitations. The standardized regression coefficients in Table 3 show the direction and relative size of the effect of each predictor on IBI. Together the predictors accounted for 41% of the variation in IBI.

TABLE 3
Standardized Regression Coefficients and R^2 for the Effects of Musical Structure, Performance Cues, and Basic and Interpretive Dimensions on Interbar Intervals (IBIs) for the Scouting Run in Session 1

Predictor Variable	Scouting Run
Musical structure	
Section	.30***
Begin section	.17*
End section	-.01
Serial position in section	.07
Switch	.05
Performance cues	
Basic	.21**
Interpretive	.05
Expressive	.04
Basic dimensions	
Fingering	.22***
Technical difficulties	.07
Familiar patterns	.15**
Interpretive dimensions	
Phrasing	-.05
Dynamics	-.13*
Tempo	.01
Pedal	-.23***
Number of notes	.01
R^2	.41***

NOTE—Positive values indicate when bars took longer to play; negative values indicate that bars were played faster.

Structure

Two effects suggest that the pianist had already formed an artistic image of how the piece should sound during this scouting run. First, the largest effect was that of sections, indicating that the four themes were played at different tempi. The C theme was fastest, the A and B themes intermediate, and the complex fugue in the long, central D section slowest. The differences may be partly due to differences in difficulty, but it seems likely that they were also a reflection of an artistic image. The same ordering of tempi occurs in the performance recorded for the CD 10 months later, where the differences reflect the expressive character given to each theme. For example, the expressive cue at the start of the C theme is "surprise" and the light, staccato playing that evokes this feeling is responsible for its faster tempo. The same artistic image was also evident in the initial sight-read performance of this section. When asked about this later, the pianist reported that she knew immediately how she wanted this section to sound the first time she played it, and the IBI data are consistent with this report.

Evidence that the pianist was paying attention to the large-scale musical structure comes from the effects of section beginnings. IBIs were longer for the first bars of the main sections of the piece than for other bars. Possibly the pianist was looking ahead to see what was coming next. Whatever the reason, the hesitations at these structural boundaries indicate that the pianist recognized formal musical structure of the piece as she played.

Performance

The effect of basic performance cues supports the pianist's claim that she was looking for the places that could be trouble spots during a performance. Basic performance cues are the fingerings, technical difficulties, and patterns that the pianist later selected to pay attention to during performance. For example, basic performance cues figured prominently when the pianist described the main landmarks of the piece that she was attending to as she played from memory in Session 17 (Chaffin et al., 2002, p. 217). These cues represent the critical details of technique that must be executed correctly in order for the performance to proceed as planned. The identification of these places in the initial scouting run reflects both of the characteristics of expertise that we are interested in: a deep understanding of the task and an anticipation of future developments.

It is unlikely that the additional time given to basic performance cues was simply a consequence of their technical difficulty. Technical difficulty was one of the basic dimensions and had no effect, probably because the main difficulties of the piece are caused by its fast tempo. Since the scouting run was under tempo, there was no need to slow down for technical difficulties.

Basic Dimensions

There were, however, effects of the other two basic dimensions that do appear to reflect problems with technique. In places where the pianist used nonstandard fingerings, she slowed down (the effect of Fingering). This is consistent with the pianist's report that she was evaluating the fingerings suggested in the score by the editor. She also slowed down in places where several different patterns of notes (e.g., scales, arpeggios, Alberti bass) overlapped or occurred in quick succession, requiring time for their integration (the effect of Familiar Patterns).

Interpretive Dimensions

There were two effects of interpretive dimensions. Bars in which the pedal was used and bars in which more notes received dynamic emphasis were played faster than other bars. It is possible that these were interpretive effects and, if so, they would represent additional evidence that playing was guided by an artistic image. It is equally likely, however, that these bars were simply easier to play. On this view, interpretive effects would have been added later by pedaling and dynamic emphasis to provide additional interest to passages that were otherwise less musically complex than the rest of the piece.

In summary, the initial sight-reading appears to have been done with an artistic image already in mind. The different tempi used for the four themes reflect both the pianist's understanding of the large-scale musical structure and her ideas about the musical character of each. More local fluctuations in tempo were consistent with the pianist's report that her goal was to scout out the piece to see where the various themes repeated, identify possible difficulties for performance, and evaluate the fingering suggestions of the editor. Like experts in other fields, the pianist began with a deep understanding of the task (Glaser & Chi, 1988). Although obliged to pay some attention to technique (the effects of Fingering and Familiar Patterns), the pianist was also looking at the big picture (the effects of Musical Structure and Performance Cues).

PRACTICE AND COMMENTS IN SESSIONS 1–12

The analyses of practice and comments during sessions 1–12 are summarized in Table 4 and Figure 1, respectively. We will give an overview of the general pattern of agreements and discrepancies between practice and comments and then examine them one session set at a time.

Table 4 gives regression coefficients and R^2 values for the effects of the predictor variables on repetitions, starts, and stops, separately for runs and work. The predictor variables together accounted for between 13% and

TABLE 4

Standardized Regression Coefficients and R^2 for the Effects of Musical Structure, Performance Cues, and Basic and Interpretive Dimensions on Number of Repetitions, Starts, and Stops For Runs and Work

	Practice Sessions 1–6						Practice Sessions 7–8					
	Runs			Work			Runs			Work		
Predictor Variable	Repeats	Starts	Stops	Repeats	Starts	Stops	Repeats	Starts	Stops	Repeats	Starts	Stops
Musical structure												
Begin section	xx	.26**	.14	xx	.26***	.22*	xx	.16	.12	xx	.03	-.02
End section	xx	-.01	.06	xx	.08	.06	xx	.02	.11	xx	.06	-.08
Serial position	-.03	xx	xx	-.09	xx	xx	-.01	xx	xx	.15*	xx	xx
Switch	.25***	.26***	.33***	.15*	.15*	.17*	-.14*	-.06	-.01	-.13*	-.03	-.05
Performance cues												
Basic	-.20*	.06	.06	.02	.08	.05	.38***	.22**	.15	.42***	.25**	.31**
Interpretive	-.15	-.02	-.01	.04	.12	.12	.03	.06	.19*	.10	.08	.17*
Expressive	-.00	.14	.03	-.03	.02	-.13	-.02	.20*	.03	-.02	.03	.01
Basic dimensions												
Fingering	.19**	.05	.08	.21**	.10	.06	.29***	.06	.18*	.03	-.09	.03
Technical difficulties	.03	.13	.17*	.20*	.14	.19*	-.03	-.01	.02	.17*	.23**	.11
Familiar patterns	.02	-.09	-.04	.16*	.11	.18*	.00	-.02	.03	-.04	-.03	-.03
Interpretive dimensions												
Phrasing	-.10	-.05	-.07	-.15*	.00	-.10	-.06	-.02	-.08	.08	.10	-.01
Dynamics	.17*	-.05	-.06	-.07	-.10	-.13	.05	-.04	-.05	-.06	-.07	-.10
Tempo	-.05	-.10	-.10	-.06	-.11	-.11	.03	.00	.07	-.05	-.06	-.03
Pedal	-.07	-.12	.02	-.02	-.08	.12	-.12	-.08	.07	.10	.12	.08
Number of notes	-.13	-.06	-.13	-.19**	-.16*	-.06	.09	.05	.00	.14*	.16*	.11
R^2	.14**	.25***	.23***	.18***	.25***	.19***	.29***	.17***	.20***	.37***	.23***	.20***

NOTE—xx indicates that predictor variable was excluded from analysis.

*$p < .05$. **$p < .01$. ***$p < .001$

	Practice Sessions 9–10						Practice Sessions 11–12					
	Runs			Work			Runs			Work		
Predictor variable	Repeats	Starts	Stops	Repeats	Starts	Stops	Repeats	Starts	Stops	Repeats	Starts	Stops
Musical structure												
Begin section	xx	.14	.19	xx	.14	.07	xx	.20*	.13	xx	.23*	.03
End section	xx	.06	.12	xx	-.02	.03	xx	.04	.04	xx	.05	.03
Serial position	.23***	xx	xx	.22***	xx	xx	.11	xx	xx	.01	xx	xx
Switch	-.15*	.01	-.13	-.18**	-.06	-.14	-.12	.11	.02	.08	.07	.08
Performance cues												
Basic	.33***	.08	.17	.09	.03	.04	.31***	.16	.25**	.03	-.08	-.07
Interpretive	.24***	.07	.18	.15	.23**	.01	.17*	.12	.14	-.03	.15	.06
Expressive	-.04	.22*	.04	.11	.07	.01	.07	.04	.04	-.05	-.04	-.01
Basic dimensions												
Fingering	.10	.05	.08	.07	.04	.00	.06	-.01	.03	.16*	.08	-.03
Technical difficulties	.05	.04	-.09	.28***	.21*	.24**	.11	.06	.09	.28***	.25**	.20*
Familiar patterns	.05	-.05	.06	.01	-.06	-.01	.06	.06	.10	.06	.10	.04
Interpretive dimensions												
Phrasing	.09	.12	.00	-.05	-.02	-.06	-.05	-.06	-.10	.13	-.03	.00
Dynamics	-.18*	-.05	-.21**	-.12	-.10	.00	-.11	-.09	-.14	.00	-.07	-.07
Tempo	-.04	-.03	.02	.04	-.08	.08	-.09	-.06	-.12	.01	-.06	-.05
Pedal	-.19**	-.08	-.07	-.06	.00	-.03	-.06	.04	.10	.14	.13	.12
Number of notes	-.01	-.05	.13	.06	.04	.08	.06	-.02	.02	-.03	-.06	-.04
R^2	.30***	.16***	.13*	.25***	.14***	.10***	.24***	.17***	.20***	.23***	.17**	.05

NOTE—xx indicates that predictor variable was excluded from analysis.
*$p < .05$. **$p < .01$. ***$p < .001$

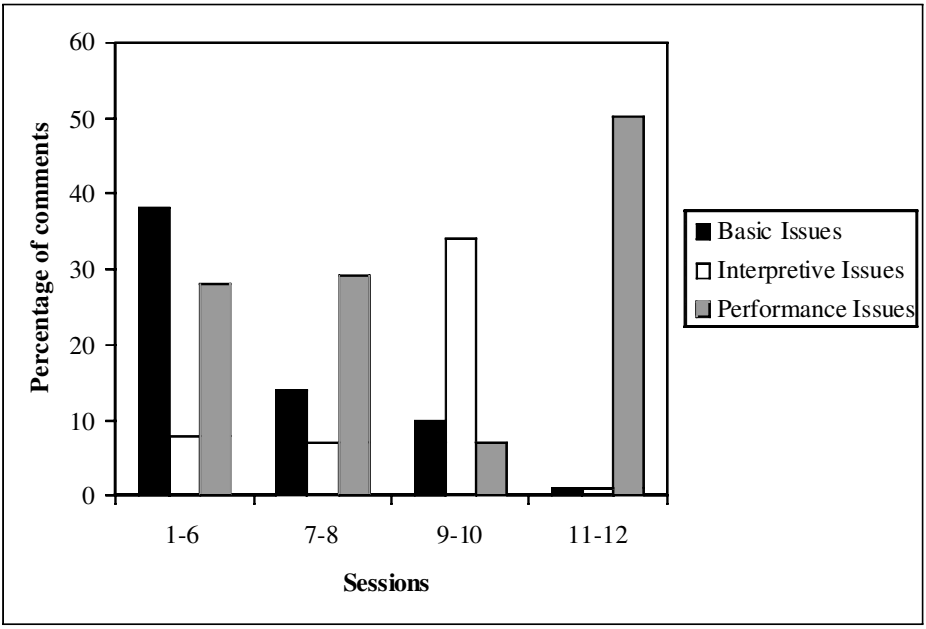

Fig. 1. Percentage of pianist's comments about basic, interpretive, and performance issues during the first 12 sessions.

30% of the variance. Statistically significant effects for a particular dimension are also shown and indicate effects that were consistent enough so that bars containing the relevant kind of feature stood out when the data were collapsed across the two or more sessions examined in each analysis. If the effect of a dimension changed during the sessions that were combined or if its effects were on bars other than the one containing the feature marked by the pianist, then its effects would not have been detected by the analyses. Given these limitations, the fact that the R^2 values were significant in every analysis suggests that, despite the small values, some of the predictors exercised strong effects on practice.

The number of significant effects for each group of variables changed across practice sessions. In Sessions 1–6, the majority of significant effects were for musical structure and basic dimensions, while performance and interpretive dimensions had very few effects. In Sessions 7–8, in contrast, performance dimensions produced the largest number of effects, while effects of structure and basic dimensions were less numerous and there were no effects for the interpretive dimensions. In Sessions 9–10, effects of two interpretive dimensions reappeared, whereas in Sessions 11–12 performance and basic dimensions again accounted for the majority of the effects.

The percentage of comments about basic, interpretive, and performance issues during the same sessions is shown in Figure 1; metacognitive comments are not included. The predominant topic of comment changed across sessions. In Sessions 1-6, basic issues of technique predominated (49 of 145 comments). In the following sessions, there were many fewer comments overall and the predominant topic changed to performance in Sessions 7–8 (8 of 28 comments), interpretation in Sessions 9–10 (14 of 41 comments), and performance again in Sessions 11–12 (10 of 20 comments).

There are striking correspondences between the results for practice and comments; also interesting discrepancies. In Sessions 1-6, basic dimensions were the predominant topic of comment and were also singled out for practice, suggesting that they were the focus of deliberate problem solving efforts. Structure was also a focus of practice but was mentioned much less frequently, suggesting that its effects were more automatic and intuitive. In Sessions 7–8, as the piece was performed fluently for the first time, practice and comments were in agreement in pointing to performance as the focus of deliberate attention. There was, nevertheless, an interesting disparity; we will see below that it was practice rather than the comments that indicate how fluent performance was achieved. In Sessions 9–10, interpretation was the focus of both practice and comments. There were three interpretive effects (compared to none in Sessions 7–8) and comments about interpretation predominated. Finally, when the pianist was "just running through the concerto" in Sessions 11–12, performance became the main topic of comment at the same time that performance and basic dimensions were again responsible for most of the effects on practice. The main focus of attention was performance, while "fix[ing] whatever goes wrong" occurred more automatically and without comment.

In the following sections, we examine the discrepancies between practice and comments in more detail in order to fill out our understanding of which decisions were made more deliberately and which more intuitively and automatically.

Sessions 1-6

The main goal of the section-by-section stage appears to have been to choose fingerings and to develop fluency and consistency of execution. Practice was affected by all three of the basic dimensions. Bars containing more fingering decisions, technical difficulties, and familiar patterns of notes were repeated more than other bars, and stops also occurred more frequently for the latter two. The comments point to the same conclusion, being mostly about fingering, technical difficulties, and familiar patterns of notes, for example,

> See, in the fingering here there are too many turns . . . so I'm eliminating them all in this one group. I hope it its going to help." (Session 4)

Sessions 1–6 appear to correspond to Wicinski's second stage of work on technical problems (Wicinski, 1950, cited in Miklaszewski, 1989).

Although technique was the main focus of attention, decisions were guided by the big musical picture. This was evident in the use of section boundaries as starting and stopping places (the effects of Begin Section) as well as in the fact that the passages practiced in each session were delimited by the formal structure. Structure also affected practice at switches that were repeated more and were the locus of more starts and stops than other bars as the different variations of each theme interfered with one another. Although the pianist mentioned structure infrequently in her comments, when she did so it was clear that she was well aware of its effects on her playing. For example, noting the difficulties caused by a switch in Session 1,

> The left hand is a problem too. . . . Instead of going to the top G,it goes to the left bottom G. (Session 1)

Other indications that work on technique was guided by larger musical goals were the effects of dynamics and phrasing. Bars containing dynamic features were repeated more during runs than other bars, and bars containing more phrases were repeated less. Dynamic emphasis was used to bring out a melodic line from the surrounding polyphony by giving each note of the line the same articulation. Decisions of this sort were, however, only mentioned when they created problems,

> Actually, I want to put the accent here . . . and that's much harder to do." (Session 4)

> Right here, it's purely a technical problem. I am having trouble because I am trying to phrase similar notes different[ly]. . . . (Session 5)

There were only 12 comments of this sort during Sessions 1–6 but they suggest that the pianist had already made many decisions about interpretation and these were influencing work on technique. In the following comment the pianist appears to acknowledge this directly.

> I've been dying to try that, to put the forte in on that. (Session 4)

Although few in number, when these comments are taken together with the effects of dynamics and phrasing on practice, it is clear that the work on technique was informed by an artistic image of how the music should sound.

Sessions 7–8

When the pianist returned to the *Presto* after 3 days of working on the first movement, the new goal was the fluent performance of the entire piece. The practice record shows that this was achieved by the practice of perfor-

mance cues, those features of the piece selected to direct performance. The speed and complexity of the *Presto* meant that retrieval from long-term memory had to be fast and reliable. This is the job of the performance cues, which function as retrieval cues, summoning the necessary responses and knowledge of the score from memory as the piece unfolds (Chaffin & Imreh, 1997, 2002). Practice of basic performance cues produced eight separate significant effects; expressive and interpretive performance cues another eight effects.

The comments were consistent with the practice data. Performance-related topics became the predominant topic and show that memory and fluency were the main concerns.

> That was memorized, as horrible as it sounds. (Session 8)
>
> The hand has a better memory if it is exercised. (Session 8)
>
> Turning pages takes your hands off and that does a lot of damage to muscle memory. (Session 8)

The comments do not, however, provide any indication of how playing fluently from memory was achieved. For this, we have to look more closely at the practice data.

In playing the piece as a whole for the first time since Session 1, the pianist was again thinking about the big musical picture. Earlier, this understanding was evident in effects of the formal structure. In Sessions 7–8 and 9–10, ideas for the musical shape of the piece were realized in a set of expressive performance cues. Bars containing expressive cues were used as starting points, indicating that the pianist was attending to these emotional turning points, implementing her artistic image of the piece.

Although expressive cues replaced section boundaries as starting places, the formal structure was still firmly established in the pianist's mental organization of the music. This was evident in the effects of serial position on repetitions in Sessions 7–8 and 9–10. Bars later in a section were repeated more than earlier bars during work and less during runs. These effects appear to be a result of the normal effect of serial position on memory whereby items later in a series are harder to remember (Broadbent, Cooper, & Broadbent, 1978; Roediger & Crowder, 1976; see Chaffin et al., 2002, pp. 210–211 for a discussion). Apparently, the pianist continued to think of the piece in terms of its formal structure, even though no longer using section boundaries as starting points.

Interpretive performance cues also affected practice in Sessions 7–8, but rather than being used as starting points, interpretive cues interrupted both runs and work, which stopped at bars containing these cues more than at other bars. One possible explanation is that the pianist was identifying the

interpretive landmarks of the piece for the first time and stopped because she was not mentally prepared to produce the effects that she wanted. If this explanation is correct, then the expressive cues came first and the interpretive cues developed later as a way of realizing the expressive goals.

The most pervasive effects on practice, however, were those of the basic performance cues, which received more repetitions, starts, and stops than other bars during work. This combination of effects is the result of playing the same bar over repeatedly, sometimes in conjunction with preceding bars, and sometimes with the bars that follow. The same pattern of effects occurred for technical difficulties in Sessions 9–10 and 11–12. It is clear why technical difficulties need to be practiced in this way: they have to be repeated over and over to develop automaticity. Automaticity was also needed for basic performance cues. The goal was to integrate head and hands so that the idea of what needed to be done, for example, a critical fingering, would automatically come to mind at the right point. What was being practiced was retrieval from long-term memory under the time constraints of the unfolding performance. The idea of the critical fingering needed to arrive in working memory at just the right moment, not so far ahead that the cue interfered with what came before, but in time to control execution of the next action (Chaffin & Imreh, 2002; Chaffin et al., 2002, chap. 9).

Although performance cues were the main focus of practice in Sessions 7–8, they were not mentioned in the comments, which were mostly about memorization. The practice of performance cues was apparently handled intuitively, without explicit labeling of the strategy or even of the cues involved (Chaffin et al., 2002, p. 188). The inability to articulate complex strategies is common in skilled behavior of all kinds (Vallacher & Wegner, 1987) and is why practice and comments should be examined together.

Sessions 9–10

The new focus of practice in Sessions 9–10 was on interpretation, and this was reflected in both practice and comments. Bars containing dynamic features and bars in which the pedal was used were repeated *less* frequently than other bars during runs. Negative effects of this sort were also characteristic of the practice of interpretive dimensions in later practice sessions and appear to reflect what we have called practice in context—the practice of effects that extend over several bars—which requires that the passage not be interrupted (Chaffin et al., 2002, p. 185). Runs also stopped more on bars where the pedal was used. Like the similar effect for interpretive performance cues, this effect appears to reflect new interpretive decision making. The pianist used pedaling as another way to bring out a theme against the background of the surrounding polyphony by giving a series of

notes the same coloring. An example of this occurred when the pianist exclaimed,

> Oh, that is a beautiful discovery. I am going to keep it like that . . . to bring out the long notes. (Session 10)

The comments were in agreement with the practice data in pointing to interpretation as the new focus. Comments about interpretation predominated, jumping from 2 in Sessions 7–8 to 14 in Sessions 9-10, for example,

> I'm trying to bring the left hand [out] and, of course, that's . . . causing problems because it is something new. (Session 9)

Remarking on the change in her playing, the pianist noted,

> It's getting there. It's fun to see some music finally coming out of it, because until now it's been pulling teeth and torture. (Session 9)

Sessions 11–12

The final two sessions of the first learning period were devoted to maintenance, playing through the piece and fixing what went wrong. The big musical picture was once again the focus of deliberate attention. The formal structure was mentioned frequently in the comments and section boundaries again served as starting places. The things that needed fixing, in contrast, were not mentioned but can be identified from their effects on practice. Basic and interpretive performance cues were repeated more than other bars during runs, and fingering and technical difficulties were repeated more during work. There were, however, no comments about these topics because all the decisions had been made earlier and the repetition of problem passages was done automatically.

Conclusions

Just as experts in other fields approach problems by first identifying the fundamental principles involved rather than focusing on superficial properties (Chi et al., 1981; Lesgold et al., 1988; Schoenfeld & Herrmann, 1982; Weiser & Shertz, 1983), the pianist in the present study approached the task of learning the *Presto* with an artistic image of the piece already in mind (Neuhaus, 1973). In her initial sight-reading, the pianist distinguished the four main themes that provide the formal structure for the piece, playing them at different tempi and marking the transition from one theme to another by taking longer on the first bar of each main section. The pianist

also identified the main landmarks of the piece that she would later use to guide performance—the basic performance cues—spending longer on bars in which these were located. These were the bars that presented particular difficulties for performance—not the immediate difficulties of sight-reading the piece at a slow tempo, but the places that would eventually become difficult when the piece was played from memory and up to tempo.

The early effects of the overall musical shape of the piece are consistent with Neuhaus's dictum that forming an artistic image is the most important first step in learning a new piece. It is not surprising that the pianist already had an image of how the *Presto* should sound during the initial sight-reading. The *Italian Concerto* is a standard of the piano repertoire and she knew it well, even though she had never played it before. Such familiarity is normal when an experienced musician starts work on a new piece. However, we would expect that, like experts in other fields (Paige & Simon, 1966), when experienced performers do not have an artistic image for a new piece, they will develop one before beginning work on technique. The pianist's image of the piece did, however, develop as practice progressed. The expressive turning points (expressive performance cues) were identified in Sessions 1–6 and served as starting points in Sessions 7–8, interpretive performance cues were established in Sessions 7–8, and additional interpretive nuances were added in Sessions 9–10.

A second characteristic of expert problem solving is the ability to make snap decisions that anticipate later developments (Chase, 1983; Glaser & Chi, 1988; Gobet & Simon, 1996). The pianist in the present study exhibited the same kind of ability to anticipate. During the initial scouting run, she used different tempi for different themes and identified the basic performance cues that she would need later to play the piece up to tempo. In Sessions 1–6, the pianist was focusing on basic issues of technique but, in spite of this, fingering decisions were shaped by interpretive considerations. In Sessions 7–8, the practice of expressive and interpretive performance cues preceded the ability to play fluently through the entire piece. It was not until Session 9 that the pianist commented "It's fun to see some music finally coming out of it, because until now it's been pulling teeth and torture." The expressive cues were identified before the pianist was able to play through the piece fluently and were no doubt responsible for its newfound musicality in Session 9.

Another way in which this practice of expressive cues in Sessions 7–8 and 9–10 is an example of anticipating later developments is that, according to the pianist's own account given in an interview after the final performance of the *Presto*, expressive cues did not become a focus of practice until the final polishing for performance. The practice data supported this account, showing that expressive cues did indeed affect practice again at the end of the second learning period, as the pianist prepared for her first

public performance (Chaffin & Imreh, 2001; Chaffin et al., 2002, pp. 190, 222–223, 243–244). The earlier effects of the expressive cues reported here for Sessions 7–8 and 9–10 thus represent an anticipation of something that became more of a focus much later in the learning process.

The pianist's comments and her activity at the keyboard provided complementary sources of information about what was happening during practice. The comments reflected the problem solving goals that were foremost in the pianist's mind. Practice revealed additional goals that were not the focus of attention and whose implementation was more automatic and intuitive. By using a multimethod approach, we were able to achieve a deeper understanding than would have been possible with either method alone.[1]

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