

A Comparison of Practice and Self-Report as Sources of Information About the Goals of Expert Practice

ROGER CHAFFIN

*Department of Psychology U-20, University of Connecticut, Storrs CT,
06269 U.S.A.*

E-mail: Roger.Chaffin@Uconn.edu

and

GABRIELA IMREH

New Jersey, U.S.A.

Abstract

A concert pianist recorded her practice as she learned the *Italian Concerto (Presto)* by J. S. Bach for performance, commenting on what she was doing as she practised. After the performance the pianist reported decisions made during practice on three basic dimensions (fingering, technical difficulties, familiar patterns of notes), four interpretative dimensions (phrasing, dynamics, tempo, pedal), and three performance dimensions representing features of the music attended to during performance (basic, interpretative, expressive). Number of features per bar served as predictor variables in regression analyses in which the predicted variables were number of starts, stops, and repetitions. Practice was divided into three separate learning periods. Practice was affected by basic dimensions in the first two periods and by interpretative dimensions in the last two periods, while performance dimensions affected practice throughout. The frequency of comments made while practising showed similar patterns, providing converging evidence for changes in the pianist's goals across the learning process. Practice and self-reports did not, however, entirely agree. Self-reports failed to mention practice of dynamics and indicated that selection of performance features occurred late in the learning process whereas practice data showed that both dynamics and performance features were practised right from the start. Practice sometimes provides information not available in self-reports.

Prolonged, deliberate practice is essential for the development of high levels of skill in any field. In every area of human achievement that has been examined, the biographies of those who have attained eminence indicate that a minimum of ten years of intensive practice preceded the achievements that made them famous (Ericsson *et al.*, 1993; Ericsson and Charness, 1994; Howe, 1990; Sloboda, 1996). This is true for fields like running that call mainly for physical skills, for fields like chess and mental calculation that depend on intellectual skills (Staszewski, 1988), and for fields like musical performance (Ericsson *et al.*, 1993; Sosniak, 1985), ballet, and figure skating (Allard and Starkes, 1991) that require a combination of both. Ten years is a minimum, exceeded only in a very small number of cases, and then by only a year or two. For the majority of the small number of people who achieve eminence, the path is longer, often much longer. The 22 young concert pianists studied by Sosniak (1985) had put in an average of 17 years of dedicated practice before achieving international recognition, and

were still a long way from establishing themselves in careers as soloists. Moreover, once a high level of proficiency has been attained, the need for practice does not stop. Continued practice is needed in order to maintain skills at a high level (Krampe and Ericsson, 1996).

The importance of prolonged practice makes it important to understand the characteristics that make some forms of practice more effective than others. Effective practice is not simply a matter of repetition. The repeated exercise of a skill, even for professional purposes, does not necessarily lead to improvement. Skill development typically stops at a stable plateau when performance reaches the level required to get the job done. Further improvement requires some additional incentive to motivate the hard work required (Bryan and Harter, 1897; 1899). Ericsson *et al.* (1993) have characterised this work as “deliberate practice”. Improvement requires setting suitable goals that are attainable from the current skill level and which lead to the development of effective strategies (Chase and Ericsson, 1981). Progress must be monitored and new routes to improvement must be continually explored (Ericsson *et al.*, 1993).

These features of deliberate practice suggest that there is much to be gained from studying the practice of experts in a field. To become an expert a person must have developed techniques and strategies for effective practice. By identifying and analysing those pedagogical techniques may be improved and our understanding of the characteristics of effective practice enlarged. The field of music is particularly well suited for this kind of study. Practice is part of most musicians’ daily routine and involves an overt, observable behaviour that is not available for purely mental skills such as calculation. The study of music practice has been handicapped, however, by the absence of suitable ways of describing practice and quantifying its characteristics. As a result, studies of practice have tended to focus on musicians’ self-reports of their problem-solving strategies and goals (Hallam, 1995a; 1995b). Even when practice has been directly observed it tends to be given rather cursory description and the focus remains on self-reports (Gruson, 1988; Hallam, 1994; Nielsen, 1997; 2000; see Hallam, 1997 for a review and see Williamon, 1999; Williamon and Valentine, 2000 for a recent exception).

Concurrent verbal reports of problem-solving activities are, of course, a well-established method for studying problem solving in domains like chess and radiology, where the problem-solving activity involves little overt behaviour (Ericsson and Simon, 1993). In music practice, however, the overt practice behaviour can provide important confirmation that the pianist is working on the goals mentioned in the concurrent reports and may provide evidence of other goals that were not reported, either because they were too automatic, too complex, too ineffable, or simply because they were less salient than other goals.

The most detailed descriptions of the practice of expert musicians are those of Miklaszewski (1989; 1995) who recorded the practice of four pianists as they learned new pieces for performance. For the pianist whose practice is described most fully, Miklaszewski (1989) provides visual representations of practice for four practice sessions during which the pianist learned Claude Debussy’s *Feux d’Artifice* up to the point that he was ready to perform it for his teacher. The pianist was a second-year student at the Chopin Academy in Warsaw who was

“acknowledged as a gifted person already possessing a high level of professional skill” (p. 98). Miklaszewski (1989; 1995) showed that practice was organised into episodes of work in which a short section of the piece was played repeatedly interspersed by longer runs, a pattern of practice that he likened to test–operate–test (TOTE) cycles (Miller, Galanter and Pribram, 1960).

In order to identify the goals of this highly structured practice activity, Miklaszewski (1989) asked the pianist to watch a video recording of the first practice session and to comment on what he was doing. Other researchers have used a similar approach (Nielsen, 1997; 2000), or have simply asked musicians to describe how they practice (Aiello, 2000a; 2000b) or how they would go about learning or memorising a new piece (Hallam, 1995a; 1995b). The pianist in Miklaszewski’s (1989) study described a range of problems presented by the initial sections of *Feux d’Artifice*, including fingering, the arrangement of the hands, the expressive qualities of the music, the correction of errors of execution, and memorisation.

The frequency of these comments provides a measure of the pianist’s concern with each type of problem. The 19% of the comments concerned with “text, music, and score” reflect the rather obvious fact that during this first practice session on a new piece the pianist’s attention was focused on the score. The 11% of comments that concerned fingering tells us that the pianist was making initial decisions about fingering. The fact that another 11% of the comments were concerned with noticing and correcting of errors and that 6% expressed like, dislike, or self-evaluation, tells us that the pianist was listening critically to what he was doing and was providing himself with the feedback that is one of the necessary ingredients of deliberate practice (Ericsson *et al.*, 1993). More surprising is the fact that in this first practice session 5% of comments were about “expressive qualities” and 9% about “fixation and memorisation”. The pianist was anticipating long-term goals right from the start, a characteristic of expert problem solving (Gobet and Simon, 1996).

While much can be learned from this kind of content analysis, two important types of information are missing. First, comments were not obtained for later sessions so that it was not possible to observe changes in the pianist’s goals as learning progressed. This omission is undoubtedly due to the heavy demands of retrospective self-reports on a pianist’s time. In the present study the pianist was asked to comment about what she was doing as she practised, thus avoiding the need for a time-consuming review of each session. A similar procedure was used in a recent study by Williamon and colleagues (Williamon, 1999; Williamon and Valentine, 2000). While contemporaneous reports may yield a less complete description of practice goals than retrospective reports (Miklaszewski, 1989; Nielsen, 1997; 2000), they do make it possible to obtain reports for every session. Contemporaneous reports also have the advantage of reflecting current thought processes rather than relying on memory (Ericsson and Simon, 1993).

The second kind of information missing from a content analysis of comments, retrospective or contemporaneous, is the link between the comments and the practice behaviour that they refer to. The musician’s comments are originally made with reference to the practice of particular passages and typically indicate the problems being addressed. This connection between practice and problem is missing from a simple compilation of the frequency of different topics. Miklaszewski (1989) does make the linkage for one passage (bars 35–38) that was the object of unusually

protracted work in session 1 by providing a copy of the score and describing the problems involved in its performance. The informative description demonstrates both the value of making this kind of connection and the impossibility of doing it in this way for an entire piece.

We take a different approach to linking practice of each passage with self-reported goals. A concert pianist (the second author) recorded herself learning a new piece for performance. In addition to commenting on her activities as she practised, the pianist provided additional, detailed (retrospective) reports about the decisions she had made about the music after the piece had been performed. Decisions about different aspects of the music, *e.g.*, fingering, phrasing, expression, etc., were reported separately. A tally of the number of decisions about each aspect of the music provided a measure of the difficulty or complexity of each passage which was then related to how each passage was practised. In this article we ask whether it is possible, using this approach, to identify effects of different kinds of musical complexity on practice and to what extent the effects that are identified correspond to the issues that the pianist mentions in comments made while practising. Do practice behaviour and contemporaneous comments identify the same problems or do they give somewhat different pictures of the learning process?

Dimensions of complexity

A pianist must attend to and make decisions about many different aspects of a piece of music during practice. These can be described by ten dimensions summarised in Table 1 (Chaffin and Imreh, 1994; 1996a; 1996b; Imreh and Chaffin, 1996). While these ten dimensions clearly are not the only way of organising the decisions a performer must make, the pianist in the present study felt that they provided an adequate framework for describing her decisions. Three *basic* dimensions (fingering, technical difficulties, and familiar patterns of notes) must be attended to simply in order to play the notes from the score. Four *interpretative* dimensions (phrasing, dynamics, tempo, and pedalling) shape the musical character of the piece.

By the time the piece is ready for performance the implementation of most of the basic and interpretative decisions has become automatic. However, an experienced performer will deliberately select some of these features to attend to in performance and will practise using them in this fashion. We refer to these features as *performance features*. Performance features serve as retrieval cues eliciting successive passages from long-term memory, they allow the pianist to keep track of progress through the piece, and they provide points of intervention for recovery from a mistake, or for the spontaneous variations that make each performance unique (Chaffin and Imreh, 1997). Performance features can be organised into three dimensions (basic, interpretative, and expressive). Basic and interpretative performance features are the subsets of the complete sets of basic and interpretative features that are selected for attention during performance. Expressive features represent an additional dimension, the emotion that the performer wants to convey to the audience.

The pianist learned the third movement (*Presto*) of J. S. Bach's *Italian Concerto*. The features reported for section C of the *Presto* (bars 77–92) are shown in

TABLE 1

Dimensions of a composition that a pianist must attend to and make decisions about while learning and performing.

BASIC DIMENSIONS: Aspects of the music that must be attended to simply to play the notes.

FAMILIAR PATTERNS – *e.g.*, scales, arpeggios, chords, rhythms.

FINGERINGS – decisions about unusual fingerings.

TECHNICAL DIFFICULTIES – places requiring attention to motor skills, *e.g.*, jumps.

INTERPRETATIVE DIMENSIONS: Decisions made during practice affecting interpretation.

PHRASING – grouping of notes that form musical units.

DYNAMICS – variations in loudness.

TEMPO – variations in speed.

PEDAL – use of pedal.

PERFORMANCE DIMENSIONS: Features requiring attention during performance.

BASIC – familiar patterns, fingering, and technical difficulties needing attention.

INTERPRETATIVE – phrasing, dynamics, tempo, pedal needing attention in performance.

EMOTIONAL EXPRESSIVENESS – emotion to be conveyed to audience, *e.g.*, surprise.

Figure 1. Each feature is marked by an arrow. Basic, interpretative and performance features are shown in separate panels. There were many more basic features reported for the second half of the section than for the first half. We asked whether the second half received correspondingly more practice and, if so, when in the learning process this occurred.

The number of features in a bar for each dimension served as a measure of the musical complexity or difficulty of that bar. The ten measures of complexity served as predictor variables in regression analyses in which the dependent variables were the number of times that the pianist started and stopped on each bar and the number of times the bar was played during a practice session. The question was whether the regression analyses would identify which dimensions the pianist was focusing on. The size of the regression coefficient for a particular dimension should indicate the degree to which the starting and stopping points in the pianist's practice were determined by the features of that dimension. The larger the effect, the more consistently the pianist was paying attention to that dimension or was having special trouble with bars containing those features.

Positive effects will indicate that bars with more of a particular kind of feature were repeated more or were the location of more starts or more stops than other

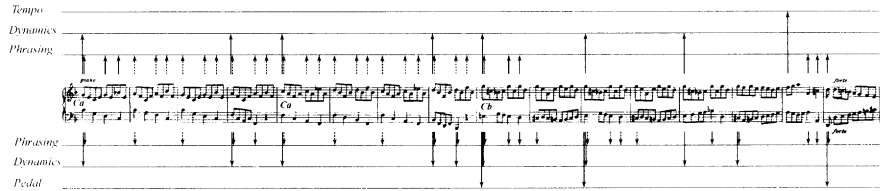
Basic Features**Interpretative Features****Performance Features**

FIG. 1

Features representing the pianist's decisions on ten dimensions for section C of the *Italian Concerto (Presto)*.

bars. For example, if the pianist is working on technical difficulties, then bars that contain technical difficulties should be repeated more than other bars, or there should be more stops and starts on these bars. Negative effects mean that the pianist is systematically avoiding a particular kind of feature. This is also evidence of attention to the dimension in question and would indicate a different kind of practice. For example, in order to practice interpretative features, such as dynamic changes, it may be important *not* to stop or start at the point where the change occurs in order to practise making the change.

Practice can be examined at different levels of detail: for an entire session, for a group of sessions, or for the whole learning process. At each level, the practice of different passages is combined across the entire piece so that characteristics of the practice of individual passages are “smoothed out” and lost, leaving a picture of the general tendency of practice across the whole time period under examination. Looking at larger swathes of practice in this way may allow identification of broader relationships between the complexities and difficulties of the music and the pianist's practice that are not obvious from the record of practice for a particular passage. An effect that appears in the regression analyses occurs consistently during the time period under consideration and its effects were large and consistent enough to show up against the background noise of all of the other factors affecting practice. The absence of an effect does not mean, however, that the pianist did not attend

to that dimension, only that the dimension did not have a consistent effect. The dimension may have influenced practice for only short periods, or it may have had different effects at different points. The regression analyses thus provide a way of viewing practice at a larger grain size than the individual episode and may indicate the pianist's overall goals during an extended period of practice.

This use of regression analysis is descriptive. The question asked is whether, during the learning of a particular piece, the pianist consistently used some kinds of features as starting or stopping places, or consistently repeated some kinds of features. The significance level for an effect, from this perspective, provides a measure of its robustness and reliability for the particular set of practice sessions analysed and can be used to identify which dimensions the pianist attended to most consistently.

To evaluate this interpretation of the regression analyses, they were compared with the results of a content analysis of the comments that the pianist made while practising. We expected that, like retrospective commentaries reported by Miklaszewski (1989) and Nielsen (1997; 2000), contemporaneous comments would reflect the problems that were the current focus of the pianist's attention. If the pianist was making decisions about fingering then we would expect to see comments about fingering accompanied by more starts, stops, or repetitions of bars containing fingering decisions. We were also interested in the possibility that the pianist's practice might address goals that she did not mention.

Method

The Pianist

The pianist, Gabriela Imreh, was trained in classical piano at the Gheorghe Dima Academy of Music in Cluj-Napoca in Romania where she studied with Harald Wagner and Nina Panieva. She made her debut at age 16 with the Romanian State Philharmonic Transylvania Orchestra. She later studied with Gyorgy Sebok and is now a concert pianist, performing principally in the U.S. and Europe. During the ten-month period covered by this study she gave about 30 concerts involving two different recital programs, and performed five concerti with orchestra, two of them for the first time. In addition, she prepared a third recital program which included the piece selected for study.

The Music

We selected the *Italian Concerto (Presto)* from the music that the pianist planned to perform during the coming year because she expected that it would be hard to learn, providing plenty of opportunity to observe the learning process. The concerto 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 three years before, but had never played the piece herself before the start of the present study. The piece consists of 210 bars in total, notated in 2/4 time and lasts for 3–4 minutes at performance tempo.

The pianist judged the piece to be moderately difficult but less so than two other pieces she was preparing for the same recording. This judgement is in agreement with published ratings which list the *Presto* as "difficult" (Faurot, 1974)

and of medium difficulty (Hinson, 1987). The *Presto* is demanding because it is fast and there are no pauses or sustained notes for the pianist to “rest” on. Moreover, like most of Bach’s keyboard music, it often departs from standard conceptual or motor patterns. Also, its complex “Italian” rondo structure, in which the same themes return repeatedly in slightly different forms, makes memorisation difficult (Chaffin and Imreh, 1997).

Procedure

Practice. The pianist recorded her practice sessions from the first time she sat down at the piano until the piece was performed without the score at the recording session. The pianist did not engage in mental practice or otherwise study the score so that the practice data represent the entire learning process with the minor exceptions noted below. Most sessions were video recorded with the camera on a tripod positioned so that the keyboard and the score were visible. Audio recordings were made of 11 sessions (26–35) for which the video camera was unavailable.

Preparation for the recording session involved a total of 57 practice sessions, of which 45 sessions were recorded. The practice recorded totalled 30 hours 11 minutes. An additional 12 sessions, totalling 3 hours 14 minutes were not recorded. Of these, session 23 consisted of a single run-through in preparation for a practice performance and the other 11 sessions (45–48 and 51–57) took place in the days leading up to the recording session. The pianist considered the piece to have been learned at this point and was running through it to maintain it in readiness.

Of the 45 recorded sessions, data are not reported here for three sessions and comments are not reported for an additional two sessions. Data for session 25 were excluded because the session was atypical, occurring as part of a discussion of the research. Data for sessions 18 and 19 were lost due to a malfunctioning microphone. The same problem led to the loss of the comments, but not the practice data, for sessions 15 and 16. Some comments were also inaudible in sessions 13–14 and 20–24 but there was sufficient data available for these sessions to be included in the content analysis of comments. In sum, practice data are reported for 42 sessions totalling 28 hours 30 minutes and comments are reported for 40 practice sessions, totalling 27 hours and 28 minutes.

Practice sessions were transcribed by recording the location in the score at which each practice segment started and stopped. A practice segment was considered to be any continuous playing of the score. Segments were considered to have ended whenever playing was not continuous in the score. For example, if a bar was repeated during a run, the repetition was treated as the beginning of a new practice segment. Short pauses and hesitations were not treated as the ends of segments if playing continued after the pause. Repetitions of the same beat (half bar) were excluded from the practice record unless they were repeated more than three times. This “stutter-rule” was adopted because in early practice sessions the pianist sometimes repeated the same note very rapidly during an otherwise fluent passage and it was considered impractical to accurately record these “stutters”. Reliability was assessed by making two independent transcriptions of the same short episodes of practice and correlating the number of starts, stops, and repetitions for each bar. Correlations between different transcribers were above .9 for starts and repetitions and above .8 for stops.

Practice was represented in cumulative practice records like those shown in Figures 2 and 3 where the score is represented on the horizontal axis and the cumulative number of repetitions on the vertical axis. The record reads from bottom left with each line representing the playing of one practice segment. Each time the pianist stopped, the record begins again on the next line up. Section C consists of three sub-sections (Ca, Ca, and Cb), whose boundaries are indicated in the figures.

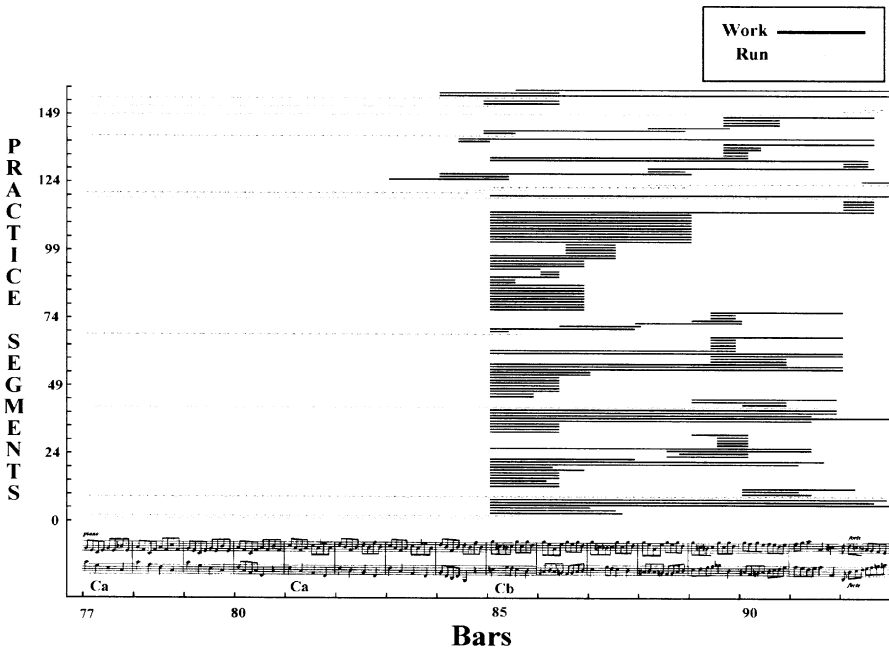


FIG. 2

Cumulative practice record for the first practice of section C of the *Italian Concerto (Presto)*.



FIG. 3

Cumulative practice record for the second practice of section C of the *Italian Concerto (Presto)*.

Formal structure. Boundaries between sections were used to divide practice into work and runs. The *Presto* is written in Italian rondo form in which the same theme returns six times separated by other musical material. Modifications of this basic structure result in 16 major sections, most of which are sub-divided, giving a total of 37 sections and sub-sections (referred to collectively as sections). The sections were identified by the pianist following session 12, the session which marked the completion of the initial learning of the piece (see Chaffin and Imreh, 1997 for a more complete description). The practice in Figures 2 and 3 shows practice of section C which consists of three sub-sections which are indicated in the figures (Ca, Ca, and Cb).

Runs and work. Practice segments were classified as runs or work by inspecting a visual representation of the practice of each session (see Figures 2 and 3). A run was defined as any practice segment or sequence of segments that covered more than two sections of the piece. Practice segments that were not part of a run were classified as work. A practice segment was classified as a run if it covered more than two sections even if it was interrupted by the repetition of short passages, so long as the interruptions occurred in different locations. This pattern of practice was interpreted as an attempt to play the longer run that was interrupted. Only when an interruption consisted of more than three repetitions of the same short passage was the run considered to have been terminated and work begun. In effect, this defined work as three or more repetitions of the same short passage. However, in order to ensure that every segment was classifiable as work or a run, work was defined formally as any practice segment that was not part of a run.

Reports of musical features. The pianist identified the features of the *Presto* that she had made decisions about during practice by marking them on copies of the score. Each feature was represented with an arrow pointing to the note representing its location, as in Figure 1. Basic, interpretative, and performance features were reported on three separate copies of the score specially prepared for the purpose. The features for section C were recorded between sessions 31 and 32 as part of the preparation for a conference presentation on the research (Chaffin and Imreh, 1994). Features for the remainder of the piece were reported approximately four months later, three months after the recording session, during a period when the pianist was engaged in listening to tapes of the recording session as part of the production process for the CD.

Comments. The pianist commented on what she was doing during each practice session, pausing briefly during practice to do so. In addition, she often gave a brief, one sentence, description of her plans for practice at the beginning of a session or at the end of the previous one. The pianist also gave an appraisal of her progress at the end of session 12 and an extended description of how she was performing the piece at the end of session 24. As noted above, all of the comments in sessions 15, 16, 18, and 19 and some of the comments in sessions 13–14 and 20–24 were inaudible.

The comments were transcribed and 23 topics of comment were identified in an initial reading of the transcripts by the first author. Three topics that received few comments were later merged with other categories to give the 20 topics listed in Table 2, which gives an example for each topic. The topics can be organised

into four broad groups. Three correspond to the organisation of the ten dimensions described above: *basic* (fingering, technical difficulties, and identification of patterns), *interpretative* (phrasing, dynamics, tempo, and use of pedal), and *performance* (memory, attention, musical structure, and use of the score). The remaining topics concerned *metacognitive* issues such as self-evaluations and descriptions of plans and strategies.

TABLE 2
Categories used in content analysis of verbal reports made during practice,
with examples.

BASIC DIMENSIONS

Fingering	<i>These are very weak fingers.</i>
Technical	<i>It sounds absolutely insane because of the large stretch.</i>
Patterns	<i>I have no idea where this motif is going. It just goes all over the place.</i>

INTERPRETATIVE DIMENSIONS

Phrasing	<i>I'm trying to emphasise this syncopation.</i>
Tempo	<i>At least there's no tempo problems.</i>
Dynamics/Pedal	<i>That gives me room for a nice crescendo.</i>
Interpretation	<i>It's really a polphonic theme . . . not theme and accompaniment.</i>

PERFORMANCE DIMENSIONS

Memory	<i>There's nothing else like it, so there is nothing to short circuit it.</i>
Musical structure	<i>I have to check every transition because every time it is something different.</i>
Use of score	<i>I'll try to play the first two pages from memory.</i>
Attention	<i>I really have to concentrate to get through it in one piece.</i>

METACOGNITIVE TOPICS

Evaluation	<i>I am still not happy with it.</i>
Affect	<i>It is miserable work.</i>
Plans + strategy	<i>What I am going to do today is just touch it up.</i>
Slow practice	<i>I am going to play it... definitely under tempo.</i>
Metronome	<i>The metronome seems to have helped.</i>
Learning process	<i>I never had to rework that section.</i>
Research process	<i>It's a little bit inconvenient to turn the machine on.</i>
Fatigue	<i>I'm going to stop because I am very tired.</i>
Editor	<i>I am going to look at another edition, because I want to know if I have options.</i>

The text was divided into short passages so that, as far as possible, each passage concerned a single topic. For the small number of passages that dealt with more than one topic, the number of topics covered was noted. The topic or topics of each passage were classified independently by the first author and a graduate student not otherwise connected with the project. The agreement rate was 86.8%, Kappa = .78. Disagreements were reconciled by discussion.

Results and Discussion

Figures 2 and 3 show the practice on the first two occasions on which the pianist worked on section C of the *Presto*, in sessions 4 and 9 respectively. The two figures illustrate three features of expert practice that are relevant to the present inquiry. First, the first eight bars (the two Ca sections) received much less practice than the second eight (section Cb), suggesting that Cb was more difficult. A likely source of this difference is shown in Figure 1: the Cb section contained more basic features (fingering decisions, technical difficulties and familiar patterns) than the Ca sections. One purpose of the regression analyses reported below was to determine whether the correlation of practice and the three types of complexity apparent in this session, also occurred in other sessions and in other sections.

A second feature of the practice is apparent when Figures 2 and 3 are compared. By session 9, the difference between sections Ca and Cb was much reduced. Session 10 contained another short episode of work similar to that in session 9 and from then on the Ca and Cb sections were treated identically. The effect of practice was to reduce and eventually eliminate differences between easier and harder passages. We may expect, therefore, that difficulties addressed in the early stages of learning a piece may not affect practice in later sessions. In the case of section C, work in three practice sessions entirely solved the problems with section Cb.

There is an interesting footnote to this account of the learning of section C. While the pianist was still learning the piece, the first author made the mistake of describing the practice record for section C during a discussion in preparation for the first conference report about the research (Chaffin and Imreh, 1994). The following day, in session 29, the pianist found it necessary to rework that section, commenting,

“I messed up . . . around [bar] 85 [the beginning of Cb]. I was thinking about what you told me yesterday, that I never had to rework that section. It bothered me . . .”.

The incident indicates the sensitivity of practice to factors that affect the difficulty of the music, even though in this case the difficulty was externally introduced.

A third characteristic of the practice shown in Figures 2 and 3 is its organisation into episodes of *work* during which the same short passage is played repeatedly separated by *runs* in which these short passages are connected with their neighbours. This organisation of practice was also noted by Miklaszewski (1989; 1995) and by Williamon (1999) and is probably a general characteristic of expert practice. Because runs and work may have different goals and may be affected by different factors, we examined the two types of practice separately.

A fourth characteristic of the practice that is apparent in Figure 2, the tendency of practice segments to start at the beginnings of sections, has been described elsewhere (Chaffin and Imreh, 1994; 1997; 1999; Chaffin, Imreh and Crawford, in preparation).

Practice Sessions

The learning of the piece was divided into three separate periods over a ten-month period (see Table 3). The first period consisted of 11 hours of practice in 12 sessions over a four-week period. Then there was an intermission of almost 15 weeks in which the piece was not practised. There were two isolated sessions halfway through this intermission and then the remaining ten sessions of the second learning period occurred in a two-week period. This second learning period provided another eight hours of practice at the end of which the pianist performed the piece in public, using the score. There was then a second intermission during which there were three isolated sessions partway through the intermission. The bulk of the third learning period began after nine weeks and totalled 14 hours of practice ending with the recording session for the CD. The total practice involved 57 sessions and 33 hours.*

The division of practice sessions into three learning periods provided a convenient division that will be used in describing the learning process.

TABLE 3
Learning periods, practice sessions and intermissions.

<i>Learning Period</i>	<i>Sessions</i>	<i>Weeks</i>	<i>Practice Time</i>	<i>Mean Session Duration</i>
1	12	4	11:19	0:57
Intermission		15		
2	12	2	8:06	0:41
Intermission		9		
3	33	11	14:00	0:25
Total	57	41	33:25	0:35

Measures of musical complexity

The complexity of each bar was computed by counting the number of features reported for each dimension. In order to determine whether the features reported provided an appropriate range of values, Table 4 gives descriptive statistics for each dimension. With the exception of tempo changes, enough features were reported for each dimension (total), so that individual bars varied in frequency (SD and range) so that a substantial number of bars contained one or more features

*The record of practice session 4 has been corrected slightly from that in Chaffin and Imreh (1997).

TABLE 4
Descriptive statistics for complexity on basic, interpretative, and performance dimensions, and for number of notes in the *Italian Concerto (Presto)*.

	<i>Total</i>	<i>Mean per Bar</i>	<i>Standard Deviation</i>	<i>Range</i>	<i>Number of Zero Values</i>
BASIC DIMENSIONS					
Fingerings	259	1.71	1.27	5	41
Technical difficulties	204	0.97	1.01	4	69
Familiar patterns	741	3.59	1.41	7	2
INTERPRETATIVE DIMENSIONS					
Phrasing	518	2.47	1.76	7	22
Dynamic changes	270	1.29	0.91	3	53
Tempo changes	5	0.02	0.15	1	205
Pedal	45	0.21	0.47	2	170
PERFORMANCE DIMENSIONS					
Basic	147	0.70	0.66	3	85
Interpretative	139	0.66	0.56	2	80
Expressive	72	0.34	0.49	2	139
OTHER					
Notes	2794	13.3	2.32	15	0

(number of zero values). In spite of the small number of tempo features, they were included in the regression analyses for the sake of completeness.

Regression analyses assume that predictor variables are relatively independent. Table 5 shows the correlation of the ten measures of complexity with each other and with the number of notes in each bar. The correlations between the dimensions were low to moderate, indicating that each measure provided independent information about a different aspect of the piece. The highest correlations were of basic performance features with technical difficulties and interpretative performance features with dynamic features. This is because the basic and interpretative performance features were sub-sets of the larger sets of basic and interpretative features and technical difficulties and dynamic features were the most likely to become performance features because they still required attention during performance. It is important to note that, in spite of this close relationship, the correlations were of only moderate strength, indicating that the basic and interpretative performance features were distinct from the complete sets of basic and interpretative features from which they were derived.

TABLE 5
Correlations of measures of musical complexity for the *Presto*.

	<i>Patterns</i>	<i>Fingers</i>	<i>Technical</i>	<i>Phrase</i>	<i>Dynamic</i>	<i>Tempo</i>	<i>Pedal</i>	<i>Basic</i>	<i>Interp. Perf.</i>	<i>Express. Perf.</i>	<i>Serial Perf.</i>
Patterns											
Fingers	0.30										
Technical	0.36	0.29									
Phrase	0.39	0.21	0.09								
Dynamic	0.14	0.29	0.16	0.24							
Tempo	0.05	0.04	0.00	0.10	0.12						
Pedal	-0.02	0.16	-0.11	0.26	0.15	0.26					
Basic	0.11	0.18	0.46	-0.01	0.35	0.02	0.09				
Interp.	0.02	0.18	0.04	0.26	0.48	0.04	0.19	0.30			
Express.	0.04	0.07	-0.10	0.24	0.35	0.15	0.33	0.25	0.45		
Serial	-0.09	-0.15	0.11	-0.21	-0.15	-0.03	-0.17	0.06	-0.02	-0.14	
Notes	0.29	0.16	0.23	0.07	0.01	-0.05	-0.22	0.13	-0.01	-0.08	0.17

TABLE 6
Regression coefficients for the effects of ten dimensions of complexity on
number of repetitions, starts, and stops during runs and work.

DIMENSIONS OF MUSICAL COMPLEXITY	LEARNING PERIOD					
	1		2		3	
	Runs	Work	Runs	Work	Runs	Work
	REPETITIONS					
BASIC DIMENSIONS						
Fingering	6.67***	4.30**	1.22*	1.50**	3.40*	1.14
Technical	1.65	9.94***	1.15	1.61*	5.07*	2.22
Patterns	0.57	2.01	-0.18	1.06*	0.29	0.43
INTERPRETATIVE DIMENSIONS						
Phrasing	-1.43	-1.46	-0.15	1.25***	0.74	-1.00
Dynamics	2.86	-4.42	-2.25*	-1.98**	-8.88***	-3.75*
Tempo	-29.77	-19.73	-2.51	-4.14	-11.25	-4.95
Pedal	-12.39*	1.55	-3.59*	-0.65	-9.84*	-2.86
PERFORMANCE DIMENSIONS						
Basic	0.91	11.47***	4.73***	4.16***	-6.37	-0.78
Interp.	-3.25	6.12	7.16***	4.43***	11.93**	6.43**
Express.	3.93	0.23	-3.48*	-3.31*	2.14	-2.62
Notes	-1.17	-0.59	0.18	0.02	0.03	-0.56
R ²	.12	.35	.27	.39	.16	.09
	STARTS					
BASIC DIMENSIONS						
Fingering	0.78	1.33	0.38*	0.60*	0.58	0.26
Technical	0.31	3.42**	-0.41	0.31	-0.01	0.50
Patterns	-0.47	0.44	-0.10	0.27	-0.10	0.17
INTERPRETATIVE DIMENSIONS						
Phrasing	0.15	0.60	0.00	0.30	0.27	-0.49
Dynamics	-0.79	-2.53	-0.24	-0.31	-0.38	-0.47
Tempo	-3.13	-12.91	-0.83	-1.50	3.32	-2.43
Pedal	-2.44*	-0.61	-0.39	-0.07	-1.72*	-0.09
PERFORMANCE DIMENSIONS						
Basic	2.91**	6.29**	0.91*	1.17*	0.87	-0.55
Interp.	0.49	5.14*	0.63	0.51	0.16	1.88
Express.	6.60***	6.89**	2.13***	1.27	2.88***	1.90
Notes	-0.41	-0.76	-0.20*	-0.16	-0.31	-0.62**
R ²	.26	.29	.21	.17	.13	.08
	STOPS					
BASIC DIMENSIONS						
Fingering	0.96**	1.06	0.34**	0.28	0.63**	0.61
Technical	0.32	2.96**	-0.40*	-0.24	0.12	0.40
Patterns	-0.08	1.08	-0.07	0.19	-0.07	0.11
INTERPRETATIVE DIMENSIONS						
Phrasing	-0.19	-0.48	-0.22*	-0.03	0.05	-0.44
Dynamics	-1.00	-2.31	-0.45*	-0.45	-0.33	-0.92
Tempo	1.17	-7.52	2.05	0.50	0.98	-0.48
Pedal	-0.00	3.28	0.37	-0.66	-1.66*	-1.26
PERFORMANCE DIMENSIONS						
Basic	2.43**	4.70**	0.61	0.57	0.03	0.01
Interp.	1.36	4.23*	0.41	1.48***	0.03	0.96
Express.	2.73**	0.50	-0.24	-0.28	0.76	-0.18
Notes	-0.23	-0.13	0.09	0.03	-0.03	-0.21
R ²	.21	.22	.13	.11	.06	.06

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

Effects of complexity on practice

Table 6 shows the regression coefficients and R^2 values for the effects of each predictor variable during runs and work for each learning period. Results for repetitions, starts, and stops are shown in separate panels. The predictor variables accounted for between 6 and 35 per cent of the variance. The R^2 values for learning periods 1 and 2 were all statistically significant ($p < .05$). Those for learning period 3 were not significant for work for any of the three measures, and were not significant for stops during runs. Given the large number of factors that might determine where a pianist starts and stops during practice, these results indicate that the pianist was being influenced by several of the dimensions. The features that the pianist reported were determining the starting and stopping points of practice segments and how often bars were repeated.

Of the 198 possible effects of the predictor variables, 56 were significant at the $p < .05$ level, 30 at $p < .01$, and 13 at $p < .001$. In order to identify a convenient number of the most consistent and robust effects, description will be limited to effects significant at the .01 level. These are summarised in Table 7, which lists significant effects for the three dependent measures together: repetitions (r), starts (s), and stops (p).

TABLE 7
Summary of significant effects ($p < .01$) of ten dimensions of complexity on number of repetitions (r), starts (s), and stops (p) during runs and work.

	<i>Learning Period</i>					
	<i>1</i>		<i>2</i>		<i>3</i>	
	<i>Runs</i>	<i>Work</i>	<i>Runs</i>	<i>Work</i>	<i>Runs</i>	<i>Work</i>
DIMENSIONS OF MUSICAL COMPLEXITY	REPETITIONS					
BASIC DIMENSIONS						
Fingering	r,p	r	p	r	p	.
Technical	.	r,s,p	.	.	.	.
Patterns	.	.	.	.	.	.
INTERPRETIVE DIMENSIONS						
Phrasing	.	.	.	r	.	.
Dynamics	.	.	.	-r	-r	.
Tempo	.	.	.	.	.	.
Pedal	.	.	.	.	.	.
PERFORMANCE DIMENSIONS						
Basic	s,p	r,s,p	r	r	.	.
Interp.	.	.	r	r,p	r	r
Express.	s,p	s	s	.	s	.
Notes	.	.	.	.	.	-s

We will look first at work during learning period 1 because this includes the work on section C shown in Figures 2 and 3. The effects for fingering and technical difficulties indicate that during work, bars containing more fingering decisions were repeated more as were bars with more technical difficulties. Work segments also tended to start and stop on technical difficulties. Familiar patterns, in contrast, had no effect. The difference in the amount of practice directed at sections Ca and Cb in Figures 2 and 3 was, therefore, due to the greater number of fingering decisions and technical difficulties in Cb, but not to the greater number of familiar patterns. The significant effects of fingering and technical difficulties show that their effects on practice were not restricted to section C, but that the same relationship was present more generally in the practice of other sections and in other sessions.

Fingerings and technical difficulties were practised in somewhat different ways. For technical difficulties, work segments more often started and stopped on the problem bar resulting in effects on starts, stops, and repetitions. Fingerings on the other hand were repeated more but were not used as starting places, indicating that practice segments often began before the difficulty. Many technical difficulties, like jumps, could be effectively practised by simply repeating the difficult motion, while non-standard fingerings needed to be incorporated into a larger motor sequence, beginning before the fingering in question.

Another difference was that bars containing fingering decisions were repeated more during runs, but bars with technical difficulties were not. The difference is probably due to the fact that features must be retrieved from long-term memory during runs. Technical difficulties tend to be remembered more easily because they are distinctive so that once learned they tend to stick. Fingerings, on the other hand, are more confusable and tend to interfere with one another. Because of this they tended to trip up the pianist during runs. The memory demands of fingerings probably also account for the third difference between fingerings and technical difficulties, that fingerings continued to receive work in learning period 2, while work on technical difficulties was completed during the first learning period. This was, again, probably due to the greater demands that fingerings place on retrieval from long-term memory, requiring more extended rehearsal to become fully automatic.

The second thing to notice about the data in Table 5 is the change in the number and the nature of the effects across the three learning periods. There were fewer effects in learning period 3 than in periods 1 and 2, probably because as complexities were mastered they ceased to affect practice. Fingering affected both runs and work in the first two learning periods, and had no significant effects in the final period. Technical difficulties affected repetitions, starts and stops in period 1, but had no effects in periods 2 or 3. The pianist was mastering the basic problems of the piece and as she did so her attention shifted increasingly to issues of interpretation.

There were no effects of interpretative dimensions in the first learning period, while in the second learning period work was affected by both phrasing and dynamics. The complexities of interpretation were also mastered in their turn. The effect of phrasing that first appeared in period 2 disappeared again in the final learning period, indicating that phrasing too had been mastered to the point that it no longer affected practice. Dynamics continued to affect practice in learning

period 3, but the effect shifted from work to runs, indicating that the pianist was sometimes interrupting runs to repeat a dynamic change. The absence of work on dynamics suggests that the problem at this point had become one of memory retrieval, being able to remember the dynamic change at the right moment to execute it accurately.

There was, thus, a shift in the focus of practice across the three learning periods from basic to interpretative dimensions. The basic dimensions produced five effects in learning period 1, two in period 2, and none in period 3. For the interpretative dimensions, on the other hand, the first effects did not appear until learning period 2 and continued into period 3. This difference was paralleled in the performance features, where the effects of basic performance features began and ended sooner than those of interpretative performance features. Basic performance features affected practice in learning period 1, while interpretative performance features did not begin to effect practice until period 2. The effects of interpretative performance features continued during the final learning period, while those of the basic performance features disappeared. Again, it appears that basic performance features had been mastered to the point that they were no longer having detectable effects on practice, whereas interpretative performance features were still interrupting runs and still needed the intensive repetition provided by work.

A third important feature of the data in Table 7 is that most of the effects were positive. This indicates that bars containing more features were repeated more or that practice segments started on these bars. This is the direction of effect to be expected if bars that are more complex or more difficult require more practice. What then of the three negative effects in Table 7? Bars with more dynamic features were repeated less than other bars during work in learning period 2 and during runs in period 3. In learning period 3, bars containing more notes were avoided as starting places.

Explanations of negative effects are more speculative than explanations of positive effects because they are less expected. Many of the dynamic features of the *Presto* involve the use of emphasis on a series of notes in order to create a theme or voice that stands out against the background of other notes. The polyphonic structure of these passages may have made them easier to learn and memorise, so that they needed less work in learning period 2 and interrupted runs less often than other passages in period 3.

Bars with more notes, on the other hand, may have been avoided as starting places in period 3 because they are expressive climaxes and therefore make poor starting points. Composers often use an increase in the density of the music as a way of creating musical tension and the *Presto* is no exception. The pianist's work in the third learning period apparently respected the expressive goals of the composer by not starting in places where the music called for an expressive climax. This does not necessarily mean that the pianist was unaware of these features in the composition during the first two learning periods, but it does suggest that other considerations had higher priority in the selection of starting points for work segments.

Fourth, two sets of performance features, basic and expressive, affected practice during the first learning period. These features were used as starting places

for work segments and basic performance features were also the focus of work, receiving more repetitions than other bars. These effects indicate that, already in the first learning period, the pianist had identified the special significance of these passages would have later on when the piece could be played fluently as a whole. The effects do not necessarily demonstrate that the pianist had selected these features to guide performance at this point, but she had singled them out for special treatment, suggesting that she was aware of their potential significance. Using these locations as starting points would have established them as retrieval cues, points in the piece where the upcoming passage can be readily retrieved from long-term memory (Chase and Ericsson, 1982; Ericsson and Kintsch, 1995). By later attending to these features during performance, the performer is able to keep track of progress through the piece and to direct attention to expressive goals (Chaffin and Imreh, 1997).

It is somewhat surprising to see that features that would later guide performance were given special attention so early in the learning process. The piece was far from ready for performance at the end of learning period 1, and the pianist did not begin to systematically practice playing without the score until session 17, in the middle of learning period 2. However, she was already laying the groundwork that would later allow her to play from memory. She demonstrated this at the end of the first learning period when she played through the piece from memory twice in order to demonstrate that it was memorised. The first attempt involved numerous stops and hesitations, but the second was more or less fluent. The effects of basic and expressive performance features in the first learning period indicate that the foundation for this demonstration had been provided by the practice of features that served as memory retrieval cues and that these were the same features that would later be selected as performance features.

Comments

The regression analyses are one way of finding out what the pianist was paying attention to during practice. Another is to look at the pianist's comments as she practised. Table 8 shows the number of comments in each learning period for each topic. Because there were many more comments in the first learning period than in periods 2 and 3 percentages are also given for the four main types of comments. The comments clearly reflected the pianist's current concerns, the focus of her problems solving activities (Chaffin and Imreh, 1997).

Basic dimensions. In the first learning period, comments about basic dimensions were frequent as the pianist made fingering decisions,

"It's a crazy, very uncomfortable fingering, but it's going to sound better and I can get away with it . . ." (session 4),

developed the motor skills to overcome technical difficulties,

"You know occasionally, although there is not any obvious technical difficulty, there is [a problem]. To hit that G is one. For some reason I keep overshooting it" (session 9),

and identified familiar patterns of notes,

"I have no idea where this motif is going. It just goes all over the place. This is one of those places ... where audio memory does not help whatsoever" (session 2).

Comments about fingering and familiar patterns became less frequent during learning periods 2 and 3 once fingering decisions had been made and patterns identified. Comments about technical difficulties persisted in period 3, however, because the pianist created new problems as she refined her interpretation,

“There is something here that bothers me so much, and it’s probably technically impossible to do... I wish there was some sort of a solution” (session 29),

and because old problems re-emerged as the tempo increased,

“There are a couple of technical problems that I’m not happy with . . . the two big leaps in left hand in bar 67 and bar 153. I’ll have to work on those” (session 30).

Interpretative dimensions. Comments about interpretative decisions were less frequent than those about basic dimensions during the first learning period, but there were enough to indicate that the pianist was making interpretative decisions about phrasing,

I’m trying to teach myself to detach those notes to emphasise this syncopation (Session 10),

and dynamics,

“I have to work in one accent that I haven’t got . . .” (session 10).

Often interpretative decisions were only mentioned because they created difficulties, e.g.,

“I’m trying to bring out more of the left hand . . . and of course that’s causing some problems because it’s something new” (session 9).

Comments about interpretation became more frequent in learning period 2, particularly in session 24 when the pianist gave a detailed description of how she was playing the piece just before her first public performance.

“In bars 8, 9, 10 and on I’m trying to lighten the sound up . . . and bring out the left hand. Just every other note, forcing it a little bit out. I’m also trying to make the theme a bit more robust with a little pedal on the ending once in a while” (session 24).

In learning period 3, interpretation became the main topic of comment, as the pianist continued to make decisions about phrasing and tempo.

“I’m making some more musical decisions. . . . There are a few themes that I want to bring up, especially when they come in left hand like [bar] 92, and also when it comes in the middle of the fugue, I want to bring it out” (session 29).

In session 31 the pianist decided to increase the tempo.

“Okay, that’s pretty exciting. I’m going to check this tempo and write it down because it’s fairly fast. . . . I would say that is an excellent tempo, and it’s metronome [marking] 132 [beats per minute], which is up there” (session 31).

This resulted in repeated references to tempo in the following sessions.

“I still feel like it’s a struggle in this tempo, and I need to work more to make the tempo comfortable. It’s very hard and sticky here” (session 33).

TABLE 8
Frequency of comments by topic during the three learning periods.

<i>Topic</i>	<i>Learning Period</i>		
	<i>1</i>	<i>2</i>	<i>3</i>
BASIC			
Fingering	36	15	0
Technical	9	7	6
Pattern	12	2	2
Total	57	24	8
%	24	16	5
INTERPRETATION			
Phrasing	11	12	7
Tempo	7	4	21
Dynamics	2	14	2
Interpretation	8	11	18
Total	26	38	44
%	11	25	28
PERFORMANCE			
Memory	22	10	7
Attention	10	13	4
Structure	28	16	2
Score	1	4	6
Total	61	43	19
%	26	28	12
METACOGNITIVE			
Evaluation	46	20	20
Affect	9	9	5
Plans + strategy	17	6	21
Slow-practice	0	0	8
Metronome	0	1	14
Learning process	10	4	4
Research process	5	5	4
Fatigue	1	0	4
Editor	0	1	2
Total	90	49	86
%	38	32	55

Performance dimensions. It was not possible to distinguish comments about performance dimensions from comments about the basic and interpretative features on which they were based. Instead, the categories of comments identified in Tables 2 and 8 as concerned with performance dealt, in one way or another, with playing from memory. There is, however, a close connection between performance features and playing from memory. One important function of performance features is to serve as retrieval cues, eliciting the upcoming passage from long-term memory, and comments about memorisation often involved identification of potential retrieval cues (Chaffin and Imreh, 1997).

The pianist thought about memorisation from the outset, for example, in choosing fingerings.

“Here I change the fingerings to be perfectly symmetrical because I know that the first finger on each beginning of a group is going to give me stability and also [helps me] to memorise it” (session 1).

In period 2, memory continued to be a matter of concern as the pianist practised playing without the score.

“Eventually, at this level [of practice], you start to have a sort of a map of the piece in your mind. And you start to sort of focus on certain places in it. I’ll try to tell you [what they are]. There are a couple of key places, like bar 7 . . . I was really concentrating on the left hand . . .” (session 17).

These “key places” are retrieval cues, many of which are performance features (Chaffin and Imreh, 1997). Learning to attend to these features at the right moment proved to be one of the main tasks in learning the piece, something that the pianist had anticipated early on.

“Now for me to actually [play it at a] tremendous speed . . . I think one of the biggest problems for performance is going to be that, literally for seven pages, . . . there’s absolutely no place to relax . . . it is pure concentration” (session 5).

Comments about the need for concentration are sprinkled through the practice sessions like a refrain.

“I ran out of steam on the last few pages and you can tell my concentration dropped dramatically” (session 17).

“I’m still cracking up here and there, but it’s getting better. The intensity of concentration that is required is amazing. If you miss any beat, you’re gone” (session 35).

An important part of memorising the piece is identifying its formal structure (Chaffin and Imreh, 1997; 1999), a process that began early on with the identification of different repetitions of the various themes.

“And here it’s basically the same theme but . . . the bottom G steps down, and, um, it’s a very subtle change” (session 4).

In session 17, as she prepared to play without the score, the pianist carefully compared different repetitions of the same theme.

“And actually there’s another conflict here, on bar . . . 25. [plays] That’s one, and the other [bar 167] is in the same key, but both turns are different. The left hand turns down in the middle and the ending is different . . .” (session 17).

Comments about use of the score were also associated with learning to play from memory.

“I’ll try to play the first page. Let’s see, how can I do this? I’ll play the first . . . two [pages] by memory . . . and keep the last page for memory again” (session 17).

Comparison with regression analyses. The regression analyses and the comments provide separate and independent sources of information about what was going on during practice. By comparing them we can see whether comments and behaviour agree with one another. By looking at the prevalence of different comments on different topics in each learning period, we can see how the pianist’s concerns changed over the course of the learning process. For example, on the basis of the results of the regression analyses, we might expect comments in early sessions to focus on basic dimensions, like fingering, and comments in later sessions to focus more on interpretation.

Just such a shift in the focus of comments is apparent in Figure 4, which shows the percentage of comments about basic, interpretative, and performance issues in each of the three learning periods. Comments about basic issues decreased across the three learning periods, while comments about interpretative issues increased and comments about performance issues remained at a fairly high level throughout but were most prevalent in learning periods 1 and 2. These trends correspond fairly well to the number of effects of basic, interpretative and performance dimensions in the regression analyses. The number of effects of basic dimensions decreased from five in learning period 1 to zero in period 3, while the number of effects of interpretative dimensions increased from zero in period 1 to two in period 2 and one in period 3. Performance dimensions, in contrast, were the only dimensions to affect practice in all three learning periods and produced more effects in periods 1 and 2 than in period 3.

It should be noted that effects of the performance dimensions cannot be directly compared with comments about particular performance related topics because, as described above, the topics and dimensions did not correspond directly. However, most of the comments that dealt with performance concerned memorisation. Because one of the main functions of performance features is to serve as retrieval cues, it makes sense to compare the frequency of comments about memorisation with evidence from the regression analyses that the pianist was paying attention to performance features. The effects of performance features in every learning period demonstrate that the pianist was paying special attention to memory retrieval cues throughout the learning process and parallel the concern with memorisation reflected in the comments about memorisation and related topics in every learning period.

The comments and the regression analyses provide converging evidence that the comments were a reliable guide to what the pianist was practising and that

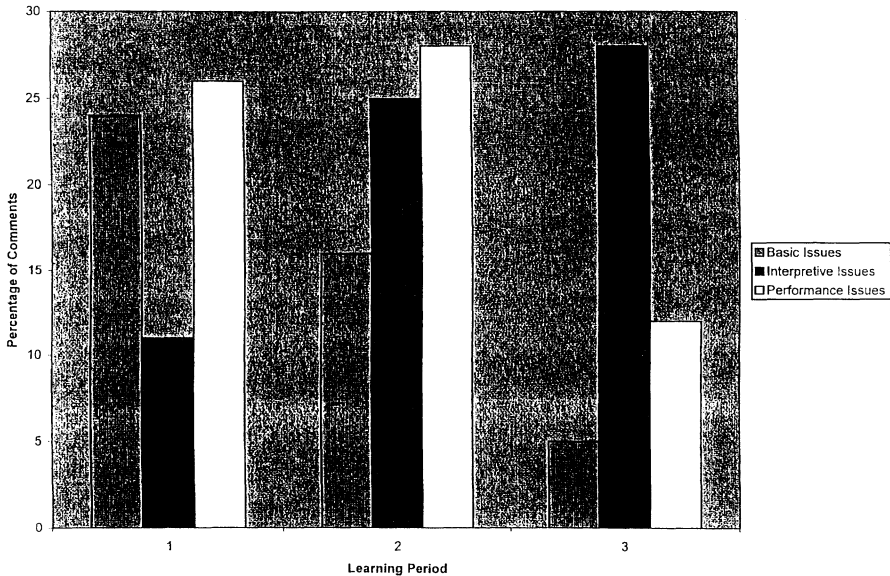


FIG. 4

Percent of comments about basic, interpretive, and performance issues by learning period.

the effects identified in the regression analyses reflected what she was attending to. Pointing to the same conclusion was a more specific correspondence between comments about fingering and the effects of fingering in the regression analyses. As comments about fingering dropped from one of the most frequent in learning period 1 to zero in period 3 there was a corresponding decrease in the number of effects of fingering on practice.

Just as important as the correspondences were the discrepancies. The most interesting discrepancy occurred for dynamic features which affected practice in learning period 3 while attracting only two comments. Dynamics also affected practice in learning period 2 and the same discrepancy was true of this period, even though Table 8 shows a substantial number of comments about dynamics for this period. In fact, the comments were all made at the end of session 24 when the pianist had stopped playing and was going through the score describing “*what I am working on*”. The pianist was, in effect, giving a retrospective report of her recent practice and it was during this retrospective description that all of the comments about dynamics occurred, *e.g.*,

“I’m still trying to do a fairly aggressive . . . [plays], just in left hand, and then I return to a very light pianissimo and again [aggressively in] just the left hand B-flat and then I return to pianissimo”.

Here the pianist is describing dynamic features retrospectively that she had made no mention of while actually practising. Any doubts about the validity of this

retrospective description are answered by the regression analyses which show that dynamic features did receive special attention during practice in learning period 2. Dynamic features appear, therefore, to be a case where the pianist practised a set of features while barely mentioning them during practice. The reason for the discrepancy appears to be straightforward. The pianist's comments during practice dealt with things that were problematic for her. Decisions about dynamic changes were straightforward and so did not attract comment. In spite of this, they affected practice and so their effects appear in the regression analyses and were mentioned when the pianist described her performance rather than her practice.

There were two other discrepancies that appear to be more apparent than real. In both cases topics that were commented on did not affect practice. In the first instance, there were almost as many comments about technical difficulties in learning period 2 as in period 1, but technical difficulties only affected practice in period 1. This discrepancy can be attributed to use of the $p < .01$ level to identify effects in the regression analyses. At the less conservative $p < .05$ level, there were two effects of technical difficulties on practice in learning period 2 corresponding to the comments on this topic.

In the second case, there were substantial numbers of comments about tempo, particularly in learning period 3, but no effect of the tempo dimension on practice. This apparent discrepancy is due to an ambiguity in the term "tempo" resulting in a lack of correspondence between the definition used in the content and regression analyses. Features of the tempo dimension represented *changes* in tempo within the piece while most of the comments about tempo referred to the overall tempo. Practice was affected by changes in tempo within the piece, while the comments were about increases in the overall tempo.

Performance features

There was another interesting discrepancy between practice and comment involving the performance features. In this case, the self-report was the pianist's account of what the performance features represented which was provided between sessions 31 and 32 when she first used these features to describe her decision making about section C. At this time the pianist reported that she had selected the performance features when she first readied the piece for performance at the end of learning period 2 and that she was continuing to review these decisions in preparing the performance for recording. Final selection of performance features had to wait until the entire work could be performed up to tempo in order to be sure which features would work effectively as retrieval cues (Chaffin and Imreh, 1997). Based on this understanding of performance features, we had expected to find their effects in learning periods 2 and 3, but not in learning period 1.

Contrary to expectation, effects of performance features were present from the beginning. The pianist was delighted by this result because it seemed to show that she had anticipated early on the musical importance of these features, even though the final decisions about them were not made until much later in the learning process. This kind of anticipation of future decisions based on prior experience is a characteristic of expert problems solving (Gobet and Simon, 1996).

Conclusions

Because deliberate practice is crucial to the development of skills and expertise of all sorts (Ericsson *et al.*, 1993), it is important to understand the characteristics that make practice more or less effective. Music practice presents an ideal opportunity to study practice in a natural setting. Making the most of this opportunity has been hampered, however, by the lack of suitable tools for describing practice and relating it to the musician's goals. Previous studies of practice have tended to focus on self-reported goals and strategies on the assumption that it is these which determine effectiveness (Gruson, 1988; Hallam, 1994; 1995a; 1995b; Nielsen, 1997; 2000; see Hallam, 1997 for a review). While this assumption is probably correct, practice behaviour provides an important and largely unexplored source of information about practice.

The procedure described in this paper for relating musical complexity and practice provides a way of relating practice to its goal that can be used over the substantial periods of practice that are involved in the acquisition of significant skills. The pianist's decisions about the music were obtained retrospectively and related to the number of repetitions, starts, and stops through multiple regression analysis. The regression coefficients reflected the degree to which practice was shaped by the features of each dimension.

Does our method provide a valid index of what a pianist is practising? The pianist's reports of complexity acquired some degree of face validity from the striking correspondence between the different amounts of practice on sections Ca and Cb and the different number of basic features reported for these sections. The regression analyses showed that this relationship was reliable for two of the three basic dimensions. The relationship between difficulty and amount of practice was present reliably across different sessions and passages for fingering and technical difficulties but not for number of familiar patterns. Further evidence that the regression effects reflected the pianist's goals during practice came from comparing them with the frequency of comments on different topics. There was a general correspondence between effects of the basic, interpretative, and performance dimensions in the regression analyses and the number of comments on topics corresponding to these dimensions. There was also a more specific correspondence between effects of the fingering dimension on practice and the number of comments about fingering.

Do the two sources of information provide different views of what is happening in practice? In four cases, self-reports and behaviour did not correspond. In two of these the lack of correspondence could be attributed to methodological problems or decisions: ambiguity in the definition of topics of comment (tempo) and use of a conservative criterion identifying effects (technical difficulties). A third case was more interesting, comments and practice provided different information about what the pianist was doing about dynamic features. The pianist made no comments about dynamics features during practice but the negative effects on repetitions in learning periods 2 and 3 indicated that she was paying attention to them. This discrepancy between comments and regression effects probably occurred because the pianist only commented on things she saw as problems. Since dynamic changes were not problematic, they received no comments even though they were being practised. Support for this interpretation came from an

impromptu retrospective description of how she planned to play the piece in her first public performance. This description contained numerous references to dynamics. Not surprisingly, contemporaneous comments did not reflect everything that the pianist was doing during practice. Some features of the piece that were routine and unproblematic were practised without attracting comment.

This example suggests that in order to obtain a full description of practice goals it may be necessary to obtain self-reports under a variety of different conditions. In the present case, attention to dynamics was evident in regression analyses that combined information about practice behaviour with retrospective reports of musical decisions, and also in a retrospective description of the piece given immediately before a performance, but not in contemporaneous comments made during practice. When self-reports obtained under different conditions provide different information, knowing what the pianist actually did in practice provides an important resource in reconciling the different accounts.

Perhaps the most interesting discrepancy between self-report and practice behaviour, however, involved yet another source of self-reported information – the pianist's description of the performance dimensions. The ten dimensions used as predictor variables represent the pianist's best effort to describe her decision making during practice. By including performance dimensions in this description the pianist was taking something of a gamble because, unlike the basic and interpretative dimensions, the idea of performance dimensions is not well attested in the pedagogical literature. The idea that a performer must practice attending to particular features of the music represents a novel hypothesis about expert practice and it was the prospect of learning more about the development of performance features that provided the pianist's principal motivation for engaging in the study. These hopes were not disappointed.

Along with the initial reports of the features on each dimension, the pianist also provided a description of what each dimension represented (Chaffin and Imreh, 1994) In this initial description, performance features were described as being selected during final preparation for performance. This account was contradicted by regression analyses that showed her singling out performance features for special attention from the start. The pianist then acknowledged that she did make tentative identifications of performance features early on in practice and that these features probably ended up as performance features 70–80% of the time. She insisted, however, that the final determination of whether a feature would function as a performance feature could only be determined by trying it at performance tempo.

These instances of disagreement between different types of self-report and between self-report and practice behaviour support our suggestion that it is important to look at practice behaviour. Practice behaviour almost certainly contains theoretically important information about practice that the musician does not or cannot provide in self-reports. In some cases, practice of a dimension may come so easily and automatically that it does not attract comment, as in the case of dynamic changes. In other cases, the interpretation of comments as relevant to a particular topic may require inferential steps that need the support from the observation of practice behaviour. For example, the identification of comments about memory, musical structure, attention, and the score as referring to performance features relies heavily on evidence that musical structure provides

the hierarchical retrieval scheme that is typical of expert memorists (Chaffin and Imreh, 1997).

We have described here one aspect of a descriptive case-study of a concert pianist learning a new piece as part of the ongoing work of her profession. In order to relate practice behaviour over many sessions to the pianist's goals in learning the piece, we found it necessary to develop new tools for the description of practice. We hope that the method can be used with other performers and adapted for use with less experienced musicians. Although our use of the basic and interpretative dimensions may be novel, the concepts involved are a commonplace of piano pedagogy and should be familiar to even fairly inexperienced pianists. The performance dimensions are a more novel idea and the deliberate practice of performance features may be something that only experienced performers engage in. Less experienced performers undoubtedly make use of performance features but their selection is probably more haphazard. It remains for future research to determine what level of experience is required for pianists to accurately identify the performance cues and other features they rely on.

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