Chapter 17

Performance cues in singing: evidence from practice and recall

Jane Ginsborg and Roger Chaffin

Abstract

Although long-term recall has been studied for many years, there have been comparatively few investigations of long-term recall for music performance. In the study described in this chapter, we examined an experienced singer's long-term recall for the words and melody of Stravinsky's *Ricercar 1,* for soprano and small instrumental ensemble. The singer recorded nine practice/rehearsal sessions with the conductor as accompanist over four weeks and wrote out the words and music from memory times over a five-year period. The musicians annotated copies of the score to indicate the location of musical features to which they attended during practice and performance cues to which they attended during performance. Comparison with the location of starts, stops, and repetitions during practice showed what the singer paid attention to. For example, attention to the musical structure was signalled by starts at beginnings of sections and phrases; attention to musical expression by the absence of starts at performance cues for expression. Comparison of the annotations with recall showed that these places had become *landmarks.* Recall was better for the first bars of sections and phrases and declined in the following bars, as distance from the cue increased. Other cues became *lacunae*—places that were forgotten, for example, performance cues for preparation where the singer attended to her next entry or to the other musicians. At these cues, recall was worse, improving as distance from the cue increased. The performance cues to which the singer reported attending on stage were prepared during the weeks that preceded the public performance and continued to affect her recall of the piece in the months and years that followed.

Jane Ginsborg writes: 'In this chapter Roger Chaffin and I report a study that directly follows up the research into singers' memorization and recall that I carried out in the course of PhD research at Keele University under the supervision of John Sloboda (Ginsborg, 2000, 2002; Ginsborg & Sloboda, 2007). The first of these studies required singers to provide verbal commentaries while practising and memorizing, and John provided the pilot data for this study, recording his practice sessions as he memorized the bass chorus part for Beethoven's Ninth Symphony. He had heard Roger talking about the research he was undertaking at the time, along similar lines, with the pianist Gabriela Imreh, and put him in touch with me, thus laying the ground for the collaboration that produced the work that we report here.'

The longitudinal case study method, pioneered by Chaffin and Imreh (1994), has been used to investigate how musicians memorize for performance. One important conclusion is that experienced musicians use performance cues, features of the music to which the musician pays attention during practice and rehearsal, and which, as a result, become mental 'landmarks' when the piece is performed. Our study extends the evidence for this conclusion to singing, as opposed to instrumental, performance; and to preparation for ensemble, as opposed to solo, performance. We also provide more extensive evidence of the effects of performance cues on written recall of the score.

Evidence for the use of performance cues comes from case studies in which solo performers video-recorded their practice sessions as they learned new works for performance. Starts, stops, and repetitions during practice indicated places in the music to which the musicians attended during practice. Their post-performance annotations of the musical score identified the decisions they had made in response to specific musical features. Spontaneous verbal comments provided evidence of the practice strategies they used. Written recall of the score after performance revealed the location of the mental landmarks in their memory of the music. Participants to date have included a classical pianist (e.g. Chaffin, Imreh, & Crawford, 2002; Chaffin, Imreh, Lemieux, & Chen, 2003), a jazz pianist (Noice, Jeffrey, Noice, & Chaffin, 2008), and a cellist (Chaffin, Lisboa, Logan, & Begosh, 2010; Lisboa, Chaffin, Schiaroli, & Barrera, 2004; Logan, Begosh, Chaffin, & Lisboa, 2007). In each study, effects of musical structure on practice were pervasive, and different aspects of technique, interpretation, and expression became the focus of attention at various points in the learning process. After the public performance, effects of performance cues on written recall of the score suggested that these places in the music had become landmarks in the musicians' mental map of the piece.

In the present study, we examined a singer (the first author) and conductor preparing Stravinsky's *Ricercar 1* for soprano and small instrumental ensemble for performance. We have previously described how the verbal comments they made during their individual practice sessions and their discussions during joint rehearsals revealed how they negotiated musical goals and established shared performance cues to coordinate their actions (Ginsborg, Chaffin, & Nicholson, 2006a). Here, we summarize behavioural evidence from the same study showing that the singer attended to performance cues during practice and that these cues affected her memory of the piece when she wrote it out from memory. Writing out the score from memory was a normal practice activity for the singer. For the purposes of the study, she wrote it out at intervals over a five-year period, providing an opportunity to observe the effects of performance cues on long-term retention.

Recall from long-term memory has been studied by psychologists ever since Ebbinghaus (1885/1913) pioneered its investigation using himself as his own experimental subject. Retention has normally been studied, however, over relatively short periods—measured in minutes, hours, or days. Relatively few studies have examined retention over months or years, although exceptions include Bahrick (1994) and Rubin (1995, 1977; Rubin & Wenzel, 1996). Most studies of musical memory have likewise focused on retention over relatively short periods. For example, listeners' recognition memory for words and music was studied by Serafine, Crowder, and Repp (1984), Serafine, Davidson, and Crowder (1986) and Crowder, Serafine, and Repp (1990). In contrast, Sloboda and Parker (1985) investigated recall for the melodies of songs by expert and novice musicians learning unfamiliar folk melodies. This showed that recall was far from verbatim, although harmonic and, especially, metrical structure was preserved—see Chapter 9, present volume. Ginsborg and Sloboda (2007), in their study of more and less musically expert singers' recall for words and melody, compared the frequency of *conjoint errors*, where both words and music are recalled incorrectly, and *separate errors*, where errors are made in words or music but not both. Both types of errors occurred, with separate errors being more frequent. This result supported the 'association-by-contiguity' hypothesis proposed by Crowder *et al.* (1990) that words and melody are stored in memory as separate but associated components. The presence of separate errors was contrary to the prediction of Crowder *et al.*'s 'physical interaction' hypothesis that words and melody are fully integrated in memory, which would have resulted in no separate errors.

In the study that provides the model for the present study of long-term musical memory (Chaffin *et al.*, 2002), the pianist Gabriela Imreh prepared Bach's *Italian Concerto* for performance in 33 hours of practice. The pianist's practice was organized in terms of the sections of the musical structure and started and stopped at performance cues more than at other locations in the piece, suggesting that she was thinking of the music in terms of its structure and paying attention to places where performance cues were needed. The effects of this attention were evident in her free recall two years later when she wrote down as much as she could remember of the first page of the score, recalling around 65% of the notes. Her recall was better at section boundaries and at expressive performance cues (places where she had to convey a particular emotion) and declined with each successive bar. Basic performance cues (relating to fingering, technical difficulties, etc.), in contrast, produced a serial position effect in the opposite direction. Recall was *worse* at basic cues and improved with distance from the cue. Similar serial position effects were also found in the study with the cellist who wrote out the 104 bars of the *Prelude* from Bach's Suite No. 6 for solo cello from memory (Chaffin, Logan, & Begosh, 2009).

The serial position effects in both of these studies suggested that beginnings of sections and expressive performance cues served as retrieval cues, providing the musicians with direct, content addressable access to their memory of the music. These places were landmarks in the musicians' mental map of the piece (Chaffin *et al.*, 2002, Chapter 9).

The bars that followed, in contrast, were cued serially by the preceding bar and so recall declined in the bars following the cue, as distance from the cue increased. Recall of an ordered series is generally better for the first item in the series and declines with each succeeding item. At each successive link in the chain there is the possibility that retrieval of the next link will fail. The probability of correct recall, therefore, decreases as distance from the start of the chain increases (Broadbent, Cooper, & Broadbent, 1978; Ebbinghaus, 1885; Fischler, Rundus, & Atkinson, 1970; Lewandowsky & Murdock, 1989; Roediger & Crowder, 1976; Rundus, 1971; Tenenbaum, Tehan, Stewart, & Christensen, 1999)—although it is also true, of course, that for verbal items there is also a recency effect by which the last items of a sequence have higher probability of recall.

In contrast to the positive effect of landmarks, recall at basic cues was *worse* than in other places and improved with distance following the cue. We will refer to such places as 'lacunae'. Lacunae occurred in places where the musician had to pay particular attention to some aspect of the sensorimotor context. For the pianist, many of the basic cues represented technical difficulties or fingerings needed to position the hand for what came next. For the cellist, basic cues represented decisions about bowing, changing string, fingering, shifting the left hand, and nuances of left hand position and intonation. One possible explanation is that attention to these details of execution during practice made them more important in the serial chain of associations cuing what came next. The absence of the usual sensorimotor context during written recall, therefore, resulted in poorer recall at these points (Chaffin & Logan, 2006). Another possibility is that the musicians relied more on the other sensorimotor context to cue their memories at these points. Since the auditory and motor cues produced by playing were not available when writing out the score, recall was poorer (Chaffin *et al.*, 2002, Ch. 7). The two explanations are not necessarily incompatible.

In summary, we expected to find that the singer started and stopped during practice at locations that were structurally important, or contained performance cues or other features requiring practice. Similarly, we expected the singer to avoid stopping and starting in places where a transition needed practice. We expected her to make both separate and conjoint errors in recall and that errors of both types would increase over time. We expected places where the singer started during practice to become landmarks in her memory and places where she needed to attend to details of technique or to the other musicians to become lacunae. We predicted that lacunae would affect recall of the bars that led up to them in addition to affecting those that followed, while effects of landmarks would be confined to bars that followed them.

Learning the *Ricercar*

Jane Ginsborg, the first author, is a former professional singer; she has worked with the pianist and conductor George Nicholson for more than 30 years, performing as a duo and as members of a variety of ensembles. In 2003, the two musicians performed Stravinsky's *Cantata* for two solo singers, women's choir, and small instrumental ensemble. The singer had performed it once before, more than 25 years earlier, and she had not looked at it in the interim. It includes one movement for solo soprano and

ensemble, *Ricercar 1* (about four minutes in length). The singer and conductor video-recorded their individual practice sessions and joint rehearsals of this piece. In this chapter we will be concerned with the singer's preparation and recall of the *Ricercar*.

Practice and rehearsal sessions

From mid-November to mid-December 2003, the singer undertook five individual practice sessions lasting four hours and 13 minutes in all (Sessions 1, 2, 3, 5, and 8); the conductor undertook one individual practice session lasting 37 minutes (Session 4). They carried out four joint rehearsals lasting two hours and 47 minutes (Sessions 6, 9, 12, and 15). These 10 practice and rehearsal sessions were video-recorded and transcribed. One brief run-through with the ensemble was video-recorded and transcribed but not analysed (Session 7); three ensemble rehearsals (57 minutes) were not recorded (Sessions 10, 13, and 14). Session 11 was the singer's first attempt to write out the words and rhythms of the work from memory. A public performance of the complete *Cantata*, conducted by George Nicholson, with the first author as solo soprano, was given on 16 December 2003. Sessions were grouped together for analysis as follows: Sessions 1 and 2 (singer learning); 3 (singer memorizing); 5 (singer briefly checking memory alone), and 6 (first of the singer's and conductor's joint rehearsals; Session 8 (individual practice session revisiting technical difficulties, and ensuring that memory was secure); Sessions 9, 12, and 15 (joint rehearsals).

Practice was transcribed by numbering the beats of the piece (1–250) and recording the beat on which each *practice segment* started and stopped. (A practice segment consisted of the uninterrupted performance of a segment of the piece and could range in length from 1 to 250 beats.) For each practice segment, we noted whether the singer's score was open or closed and classified the latter as performed from memory.

Reports

Soon after the public performance, the singer and conductor each independently reported every feature of the music that they had paid attention to during practice and rehearsal and the subset of those features that they were aware of attending to during the performance (i.e. their performance cues). They made their reports by annotating multiple copies of the score. The reports were subsequently categorized as reflecting structural, basic, interpretive, or expressive aspects of the music. The two musicians then compared their reports to identify *shared performance cues* to which they had consciously attended during the performance and to which they knew the other would be attending.

The singer made 12 types of annotation representing features requiring decisions during rehearsal and five types of annotation representing individual performance cues. She and the conductor made seven additional types of annotation representing shared performance cues. These 24 potential predictors were reduced to 16 by grouping annotations that, it was agreed by the musicians, fulfilled similar functions. Figure 17.1 shows an example of how locations were reported for three performance cues for preparation (Prepare-PC) and three for expression (Expressive-PC). The upward arrows on Figure 17.1 indicate the location of the Prepare-PCs; downward arrows indicate

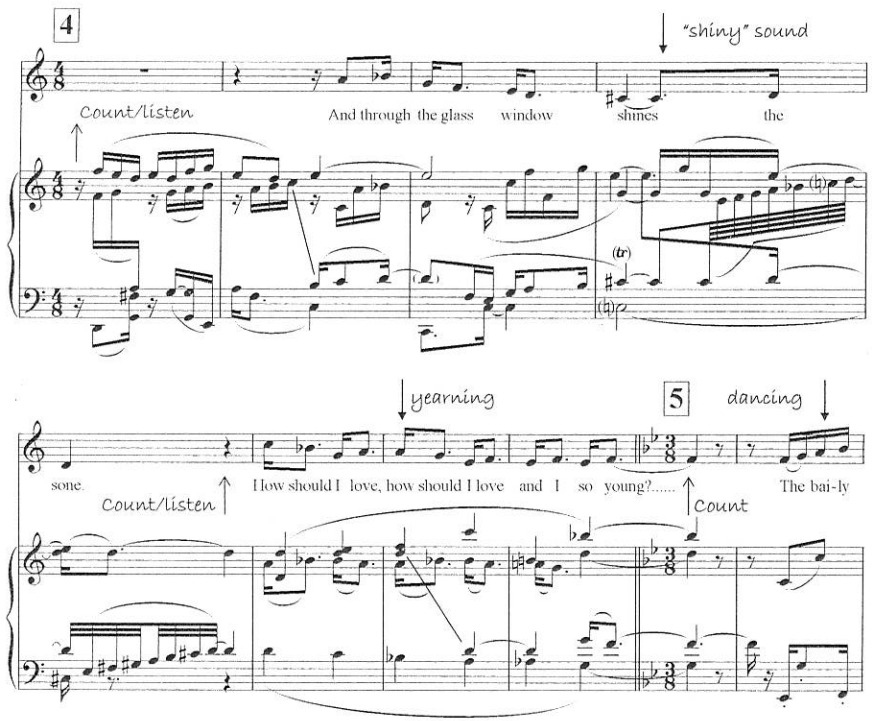

Fig. 17.1 Annotated excerpt from *Ricercar* (beats 92–129).

Expressive-PCs. The performance cues for preparation are the annotations 'count/listen' and 'count' (below the vocal line); the expressive performance cues are the annotations '"shiny" sound', 'yearning', and 'dancing' (above the vocal line). These predictor variables are listed in Table 17.1, which also shows their classification as structural, basic, interpretive, or expressive features or cues. Predictors were coded by dummy variables with '1' representing the presence of the features or cue in question and '0' representing its absence for each beat.

Memorization

The great majority of practice was done from memory. Figure 17.2 summarizes the transcription of practice in Sessions 1 and 2. Each line represents the uninterrupted performance of one segment of the piece. Grey lines indicate that the singer was practising with the score open and black lines indicate when she was practising from memory. The figure should be read from left to right and from bottom to top, with Session 1 starting in the bottom left-hand corner and Session 2 ending in the top right-hand corner. The first half of Session 1 was spent on the first two-thirds of the piece, and the second half on the final third. Most of Session 2 was also spent on the final third of the piece, which contained more new material and was rhythmically more complex than the first two thirds. Reflecting the greater complexity of the music, practice segments were shorter in Session 2 than in Session 1 ($X = 9$ and 21 beats, respectively).

Table 17.1 Singer's and conductor's annotations representing features, individual performance cues (PCs), and shared performance cues (SPCs)

Type of feature/PC	Predictor variable	No. of locations
Singer's annotations		
Structural	Start of section	9
	Switch	7
	Start of phrase	29
Basic	Prepare (count, listen, think, watch)	35
	Basic words (pronunciation)	25
	Technical (including breath)	45
Interpretive	Words (interpretation, i.e. meaning)	29
	Dynamics/tempo	9
Expressive	Expressive	15
Basic PC	Prepare PC (subset of Prepare, above)	20
	Technical (including breath) PC (subset of Technical [including breath], above)	14
Interpretive PC	Stress on words (pronunciation + meaning) PC (subset of Basic words [pronunciation] and Interpretive Words [interpretation i.e. meaning], above)	28
Expressive PC	Expressive PC (subset of Expressive, above)	12
Singer's and conductor's annotations		
Basic SPC	Score SPC (cue entry, coordinate rhythm, cadence)	11
	Arrival/off SPC	8
Expressive SPC	Expressive SPC (subset of singer's and conductor's Expressive PC)	5

Practice from memory began in Session 2. The proportion of practice segments sung from memory increased steadily from 35% in Sessions 1–2, to 64% in Session 3, 97% in Sessions 5–6, 84% in Session 8, and 100% in Sessions 9–15. The singer thus completed memorization of the piece in Session 3, referred to the score occasionally in Sessions 5, 6, and 8, and rehearsed entirely from memory in Sessions 9, 12, and 15.

Comparing reports and practice

Figure 17.3 shows the relationship between what the singer did in practice during Session 3 and her musical understanding of the piece, reported in her annotations of the score (see Figure 17.1). Practice is represented in Figure 17.2 by the horizontal lines and the singer's reports by vertical arrows representing beginnings of sections (bold faced) and phrases (regular case). The singer practised the piece section by

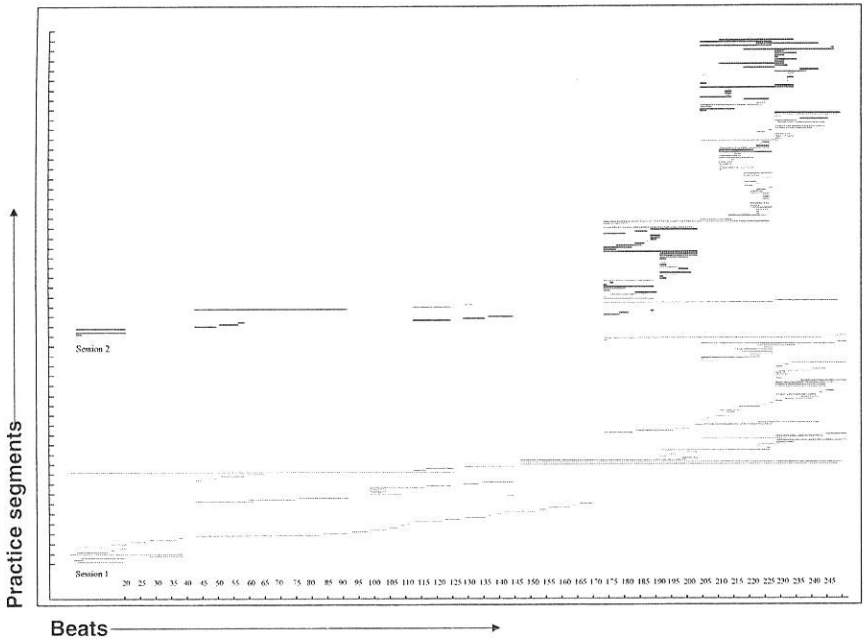

Fig. 17.2 Practice in Sessions 1 and 2 (black, from memory; grey = with score open).

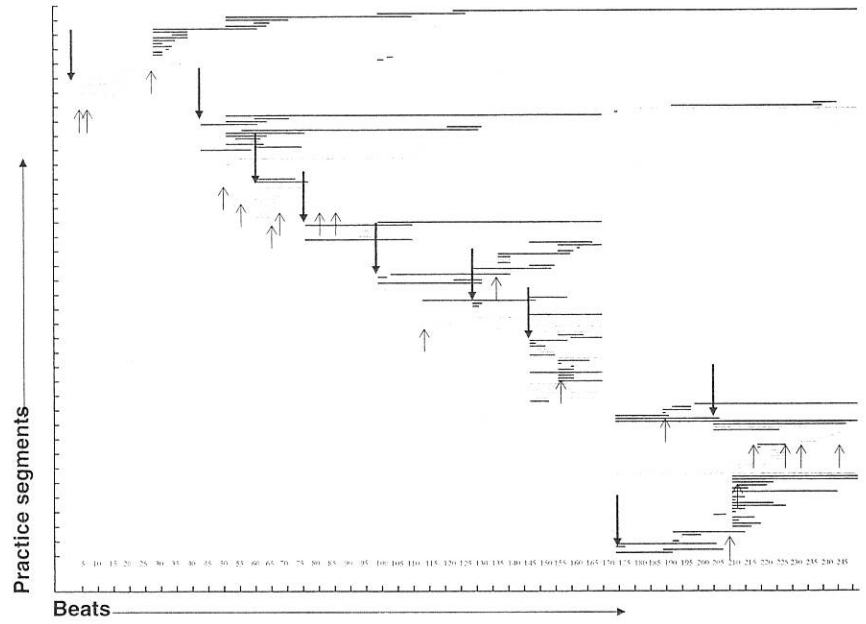

Fig. 17.3 Relating reports to practice in Session 3 (arrows down = starts of section; arrows up = start of phrase).

Table 17.2 Effects of predictor variables on location of starts, stops, and repetitions during practice showing effects across sessions

Type	Predictor variable	Estimate	Standard error	Z
Starts				
Structural	Start of section	2.589	0.360	7.199***
	Start of phrase	4.197	0.369	11.378***
Basic	Prepare	0.802	0.168	4.763***
Interpretive	Dynamics/tempo	1.606	0.320	5.023***
Expressive PC	Expressive PC	−0.983	0.372	−2.641*
Basic SPC	Score SPC	−0.959	0.294	−3.266***
Stops				
Structural	Start of phrase PC	−0.417	0.119	−3.497***
Basic SPC	Arrival/off SPC	2.843	0.184	15.468***
	Score SPC	0.571	0.163	3.509***
Repetitions				
Structural	Start of phrase	1.122	0.216	5.184***
Basic PC	Prepare PC	−0.903	0.246	−3.674***

***p <.0001, **p <.001, *p <.01.

section, starting at the end and working her way forward to the beginning. Within each section, she used beginnings of phrases as starting places. Combining the behavioural record of practice with the musician's self-reports in this way allows us to see how her practice was shaped by her understanding of the piece.

It is impractical to provide graphs for all nine sessions and 16 reports. Instead, Table 17.2 lists those relationships between reports and practice that were strong enough to reach statistical significance (p <.01) when we fitted a linear model to the data (Bryk & Raudenbush, 1992; Singer & Willett, 2003).[1] The predictor variables were the musical features and performance cues listed in Table 17.1. The dependent variables were the number of starts, stops, and repetitions for each beat. Sessions were combined for analysis into five sets, as described above (Sessions 1–2, 3, 5–6, 8, 9–15). There were no interactions of predictors with practice sessions and so all of the effects in Table 17.2 represent effects across all practice sessions. Most of the effects are positive, showing that the musicians started or stopped at the features and cues in question *more*, or repeated them more, than other places in the piece. There were three negative

[1] The hierarchical model did not assume independence of successive data points and thus modelled the dependence of successive data points in time more appropriately than the kind of standard multiple regression analysis that has been used to evaluate this kind of data in previous studies. The predictors were entered simultaneously as fixed effects. The 250 notes of the piece were divided into nine segments at section boundaries and the reliability of the effects was assessed by their consistency across sections.

effects indicating *fewer* starts, stops, or repetitions. In these cases, the musicians were playing through without stopping, usually in order to practise the feature or cue in context (Chaffin *et al.*, 2002, pp. 183–185). In either case, significant effects show that these locations received more attention and thus more practice than other places.

Table 17.2 confirms our conclusion, based on Figure 17.3, that the singer used the musical structure to organize her practice. She was more likely to start her practice segments at the beginnings of sections and phrases, to avoid stopping at beginnings of phrases, and to repeat these beginnings more (Table 17.2).[2] The analyses also confirm the conclusion drawn by Ginsborg *et al.* (2006a), on the basis of an analysis of the singer's comments during practice, that she practised performance cues including shared cues that ensured coordination with the conductor. Attention to performance cues was reflected in five effects on practice, two for individual and three for shared performance cues.

The singer avoided starting at expressive performance cues where a whole phrase needed to be sung in context in order to evoke a particular feeling, for example, to convey 'dancing' or 'yearning'. Similarly, she avoided starting at shared performance cues involving the score and was also more likely to stop at these cues (Score SPC, Table 17.2). These are places where precise coordination of an entry, rhythmic pattern, or cadential moment with the other musicians was needed. The musicians rehearsed by starting before the critical point and then playing up to or past it in order to rehearse coordinating with each other. When they stopped, it was to allow them to discuss entries or coordination. For the same reason, they were more likely to stop at the locations of the shared performance cue 'arrival/off'. Finally, the singer avoided repetition of performance cues for preparation. Many of these were places where rests were notated for the singer so that she was not singing but listening to the instrumentalists, counting beats and watching the conductor. The negative effect was probably due to the singer omitting these beats strategically to save time during her solo practice.

Starts were also influenced by three types of musical feature that did not become performance cues. The singer practised these features until they became automatic so that they no longer needed attention during performance. Practice started more often at places where she needed to prepare for what came next and where there were changes in dynamics or tempo and expression (Prepare, Dynamics/tempo, and Expressive-PCs, respectively, Table 17.2).

Recalling the *Ricercar*

The singer recalled the piece from memory in four uninterrupted performances: two during the third joint rehearsal (Session 12), with the conductor accompanying the singer on the piano, one during the final rehearsal (Session 15), and the public performance the same day. In Session 12, the singer made one error in one performance and two errors in the other. In Session 15, the singer made no errors herself but accommodated to two errors made by the conductor. The fourth, public performance was accurate in all respects.

The singer also recalled the piece from memory on nine occasions when she wrote out what she could remember of the words and melody, notating rhythms above each word, and humming, beating a pulse and conducting as necessary until she had worked through the whole song from start to end. She made the first recall (FR0) between the last two rehearsal sessions in December 2003, as part of her normal preparation for the public performance. She made two more recalls at the end of January 2004 and the end of February 2004. These yielded only one or two trivial errors and we will not report the data. The first time after the performance that the singer made a substantial number of errors was 12 months later, when she recalled the piece in February 2005 (FR1). We will report data for this and the five subsequent recalls in June 2005, August 2006, June 2007, November 2007, and November 2008 (FR2–6). Each of these recalls was made after a period of months of not thinking about the piece, before resuming work on the study. Apart from FR0, recalls occurred 12, 18, 32, 42, 47, and 59 months after the public performance. The mean time interval since last consulting the score was 6.5 months (10, 4, 10, 6, 5, and 4 months respectively for FR1, FR2, FR3, FR4, FR5, and FR6).

The first five times that the singer recalled the piece (FR0 to FR2), she engaged in additional efforts to remember the piece after working through it from start to finish once. She went back through it again, reconstructing as much as she could from memory. For the last four recalls (FR3-6) she did not attempt to reconstruct the piece but simply worked through it once from start to finish.

Scoring accuracy of recall

Each quaver beat was scored for accuracy of recall. Omitted beats were scored '0'; perfectly recalled beats were scored '1'. Beats recalled inaccurately were scored in between '0' and '1' by counting the number of different types of errors made (word, pitch, rhythm/duration.[3] Whole-beat rests were scored '1' if notated, as '0' if omitted. The exception to this rule was if notes were held too long, spilling into rests, in which case the error on the rest beat was deemed a duration error. 'Misspellings' of pitches and rhythms (e.g. $A^{\#}$ for $B^{\flat}$, a semiquaver tied to a quaver for a dotted quaver) and mis-positionings of barlines were ignored.

Accuracy of recall

Accuracy of recall declined steadily over time from 97.1% (FR0) to a low of 66.4% 47 months later (FR5; see Figure 17.4).[4] The decrease is more gradual than the typical

[2] The interaction of each predictor with sessions was tested and was significant for the effect of beginnings of phrases on starts. Separate analyses of the five session sets showed that significant effects of this predictor were limited to the singer's solo practice sessions (1–2, 3, and 8) and did not occur in sessions primarily devoted to joint practice or rehearsal (5–6, 9–15).

[3] Pitches were not recorded in FR0.

[4] A multiple regression analysis was carried out, with time (FR0–6, i.e. five days before and 14, 18, 32, 42, 47 and 59 months after the performance) as the predictor variables and accuracy of recall per beat, as outlined under 'Scoring accuracy of recall' as the dependent measure. Using the enter method, a significant model emerged: $F(7, 242) = 14.09$, $p < .0001$. The model explains 26.9% of the variance (Adjusted $R^2 = 0.269$). While accuracy of recall was not

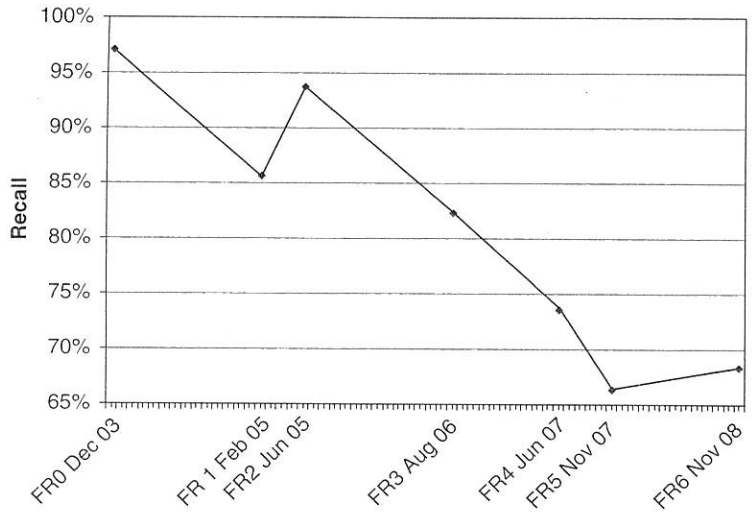

Fig. 17.4 Percentage recalled over time.

J-shaped forgetting curve (Ebbinghaus, 1885). Three factors may account for this. First, FR0 occurred as part of the singer's preparation for performance. Recall had not yet reached the level at which it was perfect, which presumably occurred five days later when the singer performed the piece from memory with complete accuracy. Second, the first three scored recalls involved reconstructions while the last four did not. Third, the singer's intermittent work on the research undoubtedly slowed forgetting. The improvement in recall between February and June 2005 may be attributable, for example, to the comparatively short period of time between the singer's analysing FR1 and undertaking FR2. Despite these factors, the decline in recall approximated the expected course, levelling off at FR5, almost four years after the performance. To our knowledge, this is the first evidence that very-long-term recall of music by a performer follows a similar trajectory of decline as other kinds of memorized material (Bahrick, 1994).

Errors in recall

Figure 17.5 shows the locations of errors in each of the seven written free recalls. The X-axes represent beats of the piece from 1 to 250. The Y-axes represent the degrees of accuracy, with 1 representing complete accuracy and 0 representing complete omission. The top panel (FR0) shows that the singer was able to notate the words and rhythms with considerable accuracy five days before the performance. There were no gaps where the music was forgotten entirely and the piece was recalled with 97.1% accuracy. The majority of errors concerned the recall and notation of rhythms (e.g. at beats 98–99 *And through*) and durations (e.g. at beats 39–40 *wolde*). Errors involving

predicted by FR0–1 or FR5–6, it was predicted by FR2 (B = 64.7, SE B = 21.8, β = 0.196, p = .003), FR3 (B = –87.3, SE B = 14.2, β = –0.41, p <0001) and FR4 (B = –59.6, SE B = 16.7, β = –0.34, p <.0001).

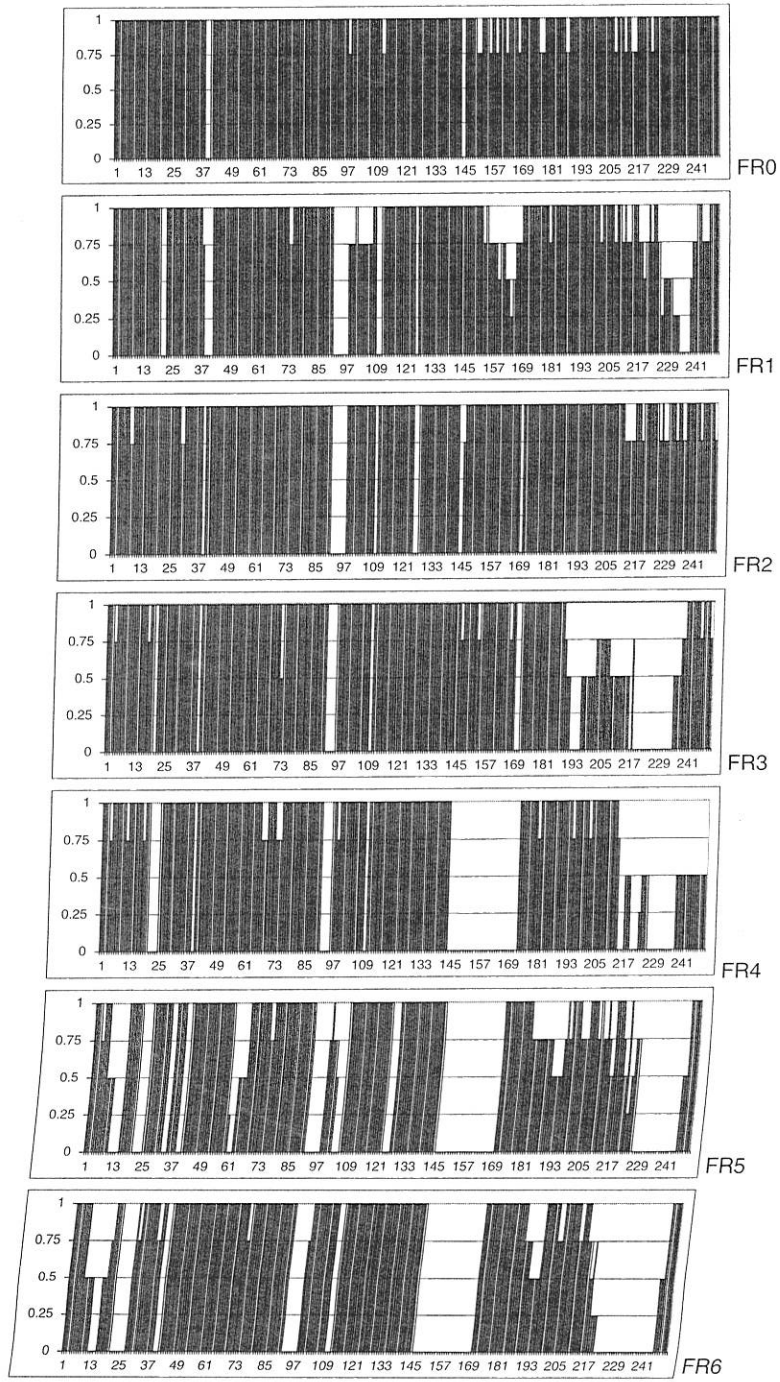

Fig. 17.5 *Accuracy and types of error in FR0–6 (see text for key).*

the words included the reversal of *now* and *were* at beats 151–152 and the substitution of *shall* for *will* on beat 156.

Fourteen months later (FR1) there was a substantial drop in accuracy, to 85.6%. The majority of errors involved rhythm and duration, although the rests after the second appearance of the refrain were omitted (beats 92–97), as was the phrase *A place e-* (beats 235–238). Four months later, 18 months after the performance (FR2), accuracy increased to 93.7%. Again, rhythm/duration errors predominated and the rests before the third appearance of the refrain were omitted. There was a substantial drop in accuracy to 82.3% after 14 months, 32 months after the performance (FR3). As well as the omitted rests (beats 92–97), the passage *and eke vic-* (beats 193–196) was forgotten. The words *Vertuous and benign* (beats 203–208) were forgotten, although the melody was recalled at first; rhythms were forgotten at *Lett us, lett us pray all, all to* (beats 209–216) before all was omitted between beats 219–234 (*Eternal Which is the hevenly King After ther liff grant them*).

Recall continued its slow deterioration in FR4, 10 months later and 42 months after the performance. Accuracy dropped to 73.5% as the whole of the section following the third appearance of the refrain was forgotten: *For to report it now were tedius: We will therfor now sing no more Of the games joyus* (beats 145–172). The majority of errors were durations, forgetting the melody but preserving the words or omitting words and melody simultaneously. There was one pitch error that had not occurred before (*All*, beat 214), after which the next three words were forgotten (preserving the melody), and then the subsequent melody (preserving the words) before both words and melody were forgotten altogether, as before: *After ther liff grant them A place* (beats 227–237). The words *eternally to sing* (beats 238–244) were forgotten, although not the melody, and the final *Amen* was recalled only with rhythmic errors.

The next recall (FR5), five months later and 47 months after the performance, showed more substantial decline: accuracy dropped to 64.4%. Portions of the very first line were omitted along with the section following the third appearance of the refrain (as in FR4) and the words of *Our quen princis* (beats 182–189), as well as the closing section starting *After ther liff* (beats 227–244). Finally, many of the same passages were forgotten again in FR6, a year later and 59 months after the performance. Accuracy of recall improved slightly, to 68.3%, including recall for two previously forgotten phrases, *And through the glass window shines the sone* (beats 98–109) and *Our quen princis* (beats 182–189).

Conjoint versus separate errors

Errors and omissions were classified as conjoint (errors or omissions in both words and melody, i.e. pitch and rhythm combined) or separate (errors or omissions of words, duration, pitch, or melody). Conjoint and separate errors and omissions were calculated as a proportion of all beats (Figure 17.6). Those involving omissions of both words and melody (conjoint omissions) increased across recalls to 26% of all beats in FR6 (the passages represented as white gaps in Figure 17.5), while conjoint errors peaked in FR3 at 6.8%. The proportion of separate errors declined from a high of 5.6% in FR1 to zero in FR 2 and 5, while the proportion of separate errors involving pitch

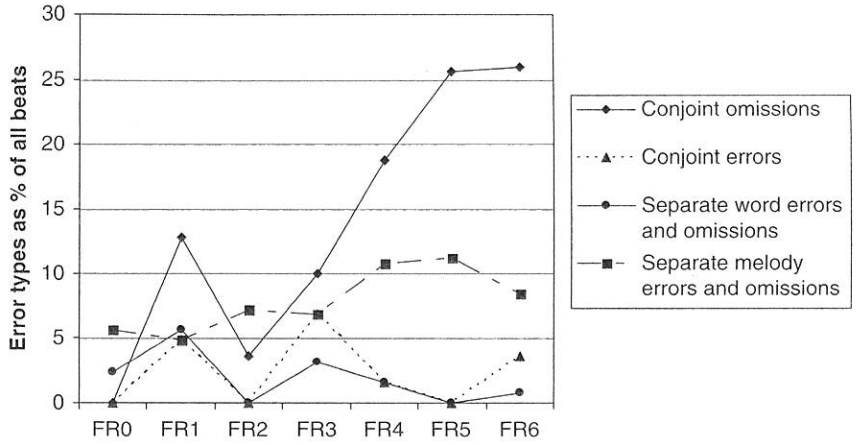

Fig. 17.6 Percentage of all beats constituting conjoint omissions, errors, and separate word and melody errors/omissions in FR0–6.

and rhythm/duration increased to a peak of 11.2% in FR5.[5] Our results are consistent with those of Ginsborg and Sloboda (2007) showing that expert singers make both conjoint and separate errors and that the latter are more numerous. The presence of some separate errors indicates that the singer was able to recall words and music separately. Contrary to the prediction of Crowder *et al.*'s (1990) physical interaction hypothesis, it was not the case that words and melody became inseparable in memory. On the other hand, the preponderance of conjoint errors, including omissions, supported the association-by-contiguity hypothesis that memory for words and music support each other by providing multiple retrieval cues.

Landmarks and lacunae

We found landmarks in the singer's memory—places that she recalled better than surrounding passages. We also found lacunae—places that she recalled worse. Both were indicated by serial position effects in the accuracy of recall. The bar graphs in Figure 17.7 shows mean recall probability as a function of serial position following starts of sections (top left), performance cues for stress on words (top right), and performance cues for preparation (bottom left). The beat where the report was marked was assigned the serial position '0'. For SP-after, any beats that followed in the same bar were also coded '0'. Beats in the next bar were assigned the serial position '1'. Each succeeding bar was numbered successively ('2', '3', '4') up until the next report of the same type, with a maximum value of 4. Serial positions of 4 and greater received the same value to provide the same number of serial positions for all predictors.

[5] A multivariate repeated measures MANOVA with one within-subjects factor (time, as above) and seven different dependent variables—the mean of the numbers of errors of each type (none = 0, separate melody = 1, separate word = 2, conjoint error = 3 and conjoint omission = 4) made on each occasion–revealed a significant effect of time: $F(6, 244) = 27.02$, $p < .0001$ (Pillai's Trace), such that mean scores rose from .1 (SD = .02) in FR0 to 1.3 (SD = .11) in FR6.

Table 17.3 Effects of predictor variables on recall showing effects across sessions

Type	Predictor variable	Estimate	Standard error	Z
Structural	Start of section	−0.038	0.008	−5.02***
Interpretive PC	Stress on words	−0.034	0.009	−3.835***
Basic PC	Prepare	0.017	0.009	1.98*
Interpretive	Dynamics/tempo	1.606	0.320	5.023***

***p <.0001, **p <.001, *p <.01.

The line graphs shown in Figure 17.7 represent the values predicted by the linear model that we fitted to these data representing the effects of serial position. Table 17.3 summarizes the analysis that tested the fit of the model to the data. FR0 and FR2 were omitted from this analysis, and from the data summarized in Figure 17.7, because their low error rates produced negligible serial position effects. We report serial position effects for the three predictors that had significant linear effects. These provide the clearest evidence for the presence of landmarks and lacunae in the singer's memory and were the most similar to those observed in previous studies. Two additional predictors had non-linear effects that are not easily interpreted and are not described here.[6]

At starts of sections and performance cues for stress on words, probability of recall was highest at the cue. Recall decreased stepwise with distance from starts of sections. At performance cues for stress on words, the higher probability of recall persisted for two bars before declining. These effects suggest that these were the main landmarks in the singer's memory, providing direct, content addressable access to these places in the piece. Once the beginning of each passage was retrieved, it cued recall of what followed until, at some point, a link failed and the chain was broken, resulting in poorer recall as distance from the landmark increased (Roediger & Crowder, 1976).

It is not surprising that starts of sections would be landmarks in a musician's memory, since these are the main divisions in the textual and/or musical material and were often used as starting places during practice (see Table 17.2). Performance cues for stress on words, in contrast, were not singled out as starting points for practice. These were places where the singer's interpretation of the composer's intentions required that the meaning of the text be conveyed by stress on a particular word or group of words. At '*prepotent*', for example, the singer made the annotation 'powerful before and after' to indicate the sense of power she wished to indicate as she sang the remainder of the phrase, '*prepotent and eke victorious*'. Apparently, interpretive landmarks of this sort were as distinctive in memory as the starts of sections and their positive effects on recall extended further.

Performance cues for preparation reminded the singer of what came next. The probability of recall was lowest at these basic cues and improved as distance from the cue increased. The serial position effect was thus in the opposite direction from that described for starts of sections and performance cues for stress on words. Many performance cues for preparation occurred in places where the singer needed to watch the conductor and listen to the other instrumentalists. Some of these cues occurred during rests as the singer prepared for an entry. Because rests were generally recalled less well than material that had to be sung, rests were excluded from the analysis. Accordingly, the effect shown in Figure 17.7 is based on recall for sung passages. It is perhaps not surprising that the singer's memory for these passages would be weaker. One explanation is that attention to the other musicians decreased her attention to the music, resulting in weaker memory. Another, not incompatible, possibility is that the singer relied more on the other musicians to cue her memory for the music at these points. Their absence, when she wrote out the score, resulted in poorer recall.

The results are remarkably similar to the two other studies that have looked at serial position effects for performance cues in written recall (Chaffin, Ginsborg, & Dixon, 2009a; Chaffin *et al.*, 2002, pp. 212–216). In each case, there were the same negative

[6] Expressive features and dynamic/tempo features resulted in significant but non-linear effects. We are continuing to explore these data by looking at serial position effects both before and after these features and will report the results of these additional analyses on a later occasion.

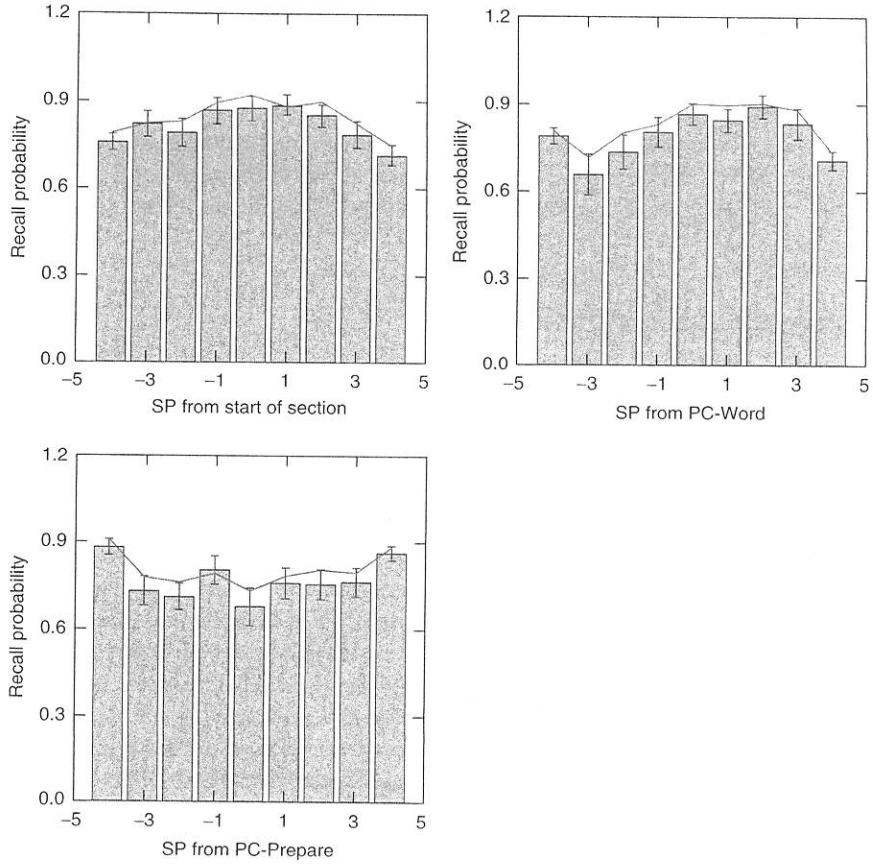

Fig. 17.7 Mean probability of correct recall in FR1, 3, 4, 5, and 6, four bars before and after cues of each type.

serial position effects for structural boundaries (i.e. starts of sections) and positive serial position effects for basic performance cues (i.e. preparation). The instrumentalists in earlier studies did not have any performance cues that were directly comparable with the singer's performance cues for stress on words and in those studies interpretive cues did not produce significant serial position effects. For the singer, places that were critical in determining the meaning of the text played the same role in memory as the expressive turning points in the music played for the instrumentalists in the earlier studies.

Summary and conclusions

Like other experienced soloists who have been studied, the singer engaged in extended practice to ensure that recall occurred with the rapidity and fluency needed for performance (Chaffin & Logan, 2006). The singer had the piece memorized by Session 3, in which she sang 64% of the practice segments from memory. In the following sessions, she continued to practise mainly from memory. In the process, she developed the automaticity and reliability of memory retrieval needed for a secure performance. When she checked her memory by writing out the words and rhythms for the first time (FR0), five days before the performance, there were no gaps; her memory was 97.1% accurate. As she progressively forgot the piece in the months and years that followed, the increasing gaps in subsequent recalls revealed how the music was organized in her memory. Serial position effects identify the location of landmarks in her mental map of the piece and of lacunae, where her memory was weak.

The practice records show how landmarks were established. From the outset, the singer organized her practice by sections and used beginnings of sections and phrases as starting points during practice. In order to start at these places, she had first to think of the words and melody and then start singing. This established a link between the thought and the action. Later, just thinking of the place was sufficient to bring the relevant passage to mind, providing content addressable access to the piece at this point. With further practice, the link became rapid and reliable. In this way, the singer internalized the hierarchical formal structure of the music as a retrieval organization for her memory of the *Ricercar* (Chaffin & Imreh, 2002).

Evidence that the singer's memory for the piece was organized in this way was provided by written recall of the score. Memory was best at starts of sections and performance cues for stress on words and diminished with as distance beyond these landmarks increased. Other performance cues, such as those for preparation, produced lacunae. In these cases, memory was weakest at the cue. The probability of correct recall decreased as the singer approached each cue but increased with distance from it. We suggested that landmarks were recalled better because they could be directly accessed by content address when serial cuing by the preceding context faltered. Serial cuing of subsequent bars then produced the characteristic negative serial position effect as the probabilities of forgetting at each beat accumulate with increasing distance from the cue. Alternatively, landmarks may have been recalled better because they received more attention during practice and were therefore encoded more securely. The two explanations are not necessarily inconsistent.

Lacunae occurred in places where attention to other aspects of the performance distracted the singer's attention. For example, recall was worse at performance cues for preparation and improved linearly as distance from the cue increased. This effect suggests that when the singer needed to think about something else (her next entry, other musicians), her memory for words and music was weakened. Recall was weakest at the focal point of attention, at the cue, and improved progressively as distance from the distraction increased. Similar effects, both positive and negative, have been obtained in two other studies in which performers wrote out the score of a memorized piece. In the case studies of a pianist and cellist mentioned earlier, landmarks were observed at structural and expressive performance cues. Recall was higher at the cue and decreased with distance in the bars that followed (Chaffin & Imreh, 2002; Chaffin *et al.*, 2010). Lacunae were also observed in the same studies, although the authors did not use the term, at basic cues requiring attention to technique. The present study confirms the earlier findings with a much more extensive body of recall data: seven recalls over five years.

Did the singer's expectations about the study shape our findings? The need to record herself undoubtedly affected some aspects of her practice. In the early stages of memorizing, for example, she refrained from moving around the studio while singing because this would have rendered her invisible to the camera, which was in a fixed position. So she confined herself to sitting at the piano in her first four practice sessions. We think it unlikely, however, that the memorization strategies we have described were much affected by the presence of the camera or the anticipation of reporting decisions. Preparation for the public performance was always her overriding concern and for this she needed to rely on well-established practice strategies. We have already suggested that the process of recalling the *Ricercar* for the purposes of the research and analysing her recall may have slowed forgetting of the piece, even though she followed the instruction always given to participants in her own studies: not to think about the words or melody except during deliberate recall for the purposes of the research.

We believe that our conclusions apply to most experienced performers. To perform reliably from memory requires that memory retrieval be practised. Musicians sometimes find themselves in the position of having to perform from memory without adequate preparation. In these cases, they must rely on serial cuing. Often they get away with it. But most musicians prefer to have a safety net. Performance cues providing content addressable access to memory provide a back-up, just in case. If things go wrong, the musician can jump forward to the next cue and avoid the ignominy of having to go back and start over. The singer in our study, following her normal practice, tested her safety net by writing out the words and rhythms of the melody from memory five days before the performance. Although most performers may not test their memories so thoroughly, we believe that most do set up performance cues and practise their use.

Performance cues differ, of course, as a function of the piece, musical style, instrument, experience of the musician, and demands of the particular occasion. No doubt, there are also individual differences between musicians in the extent to which they establish performance cues rather than relying only on serial cuing. The studies of

professional performers to date suggest, however, that most musicians make use of both (Chaffin, 2007; Chaffin & Imreh, 2002; Ginsborg, Chaffin, & Nicholson, 2006b; Noice *et al.*, 2008). This generalization is also suggested by the consistency of the findings from case studies of musicians with general principles of memory (Ericsson & Kintsch, 1995). Musicians' use of musical structure and performance cues is consistent with principles of expert memory developed from the study of experts in other fields, and with principles of memory derived from the study of the general population (Ericsson & Oliver, 1989). There is good reason to expect, therefore, that the same principles generalize to other experienced performers.

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Part 7

Music and cultural integration