Serial Position Effects in a Singer's Long Term Recall Identify Landmarks and Lacunae in Memory

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ABSTRACT

An experienced singer learned Stravinsky's *Ricercar 1*, for soprano and small instrumental ensemble for public performance and annotated copies of the score to indicate the location of musical features that she attended to during practice and performance cues that she attended to during performance. During the next five years, she wrote out the words and music from memory six times. Recall was initially perfect, but declined over time as portions of the piece were progressively forgotten. *Landmarks* in recall were marked by a sharp increase in the probability of recall followed by a gradual, linear decrease as the serial cuing of successive bars broke down. Landmarks occurred at important points in the music (structural boundaries and interpretive performance cues) where retrieval cues provided content addressable access to memory, allowing the singer to restart the chain of associations after interruption by a gap where the music was forgotten. *Lacunae* occurred at places where the singer attended to the other musicians (shared performance cues for arrival/off). The probability of recall progressively decreased in bars preceding lacunae and then increased again in the bars that followed. Serial position effects in her written recall of the score thus revealed which aspects of the music the singer had attended to during practice.

INTRODUCTION

When a piece of music is first learned, memory for what comes next is activated by *serial cuing* as the current passage cues motor and auditory memory for what comes next. During memorization, serial memory is supplemented by *content addressable* access. A memory is content addressable if you can ask yourself, e.g., "How does the third repetition of the main theme go?", and the music comes to mind (Chaffin, Logan & Begosh, 2009; Rubin, 2006). In music performance, associative chaining primarily involves motor and auditory memory and is largely implicit; it can only be demonstrated by actually playing. Content addressable memory, in contrast, is declarative and explicit; it can be demonstrated by talking about it or writing it down.

In the present study we examined a singer's declarative, content addressable memory for a piece that she had memorized for performance. The singer who we studied was the second author of this paper. Our study builds on her previous research on the recall of other singers (Ginsborg, 2000, 2002; Ginsborg & Sloboda, 2007). She repeatedly wrote out the score from memory over a five-year period at intervals of approximately a year. Writing out the score from memory was a normal practice activity for the singer and provided an opportunity to observe recall when gaps in memory interrupted the normal process of serial cuing, forcing the singer to rely on content addressable retrieval.

To perform from memory, a musician must smoothly integrate serial cuing and content addressable access. As one pianist put it in talking about her learning the *Italian Concerto (Presto)* by J.S. Bach:

"My fingers were playing the notes just fine. The practice I needed was in my head. I had to learn to keep track of where I was. It was a matter of learning exactly what I needed to be thinking of as I played, and at exactly what point so that as I approached a switching point I would automatically think about where I was, and which way the switch would go" (Chaffin, Imreh & Crawford, 2002, p. 224).

The musician was talking about the need to practice *performance cues.* Performance cues are retrieval cues, places where the musician can think, e.g. "3rd repetition", and start playing. Because they can be accessed both by serial cuing and directly, by address, performance cues provide a safety net in case serial cuing breaks down. Careful preparation of performance cues makes it possible for experienced soloists to reliably perform challenging works from memory on the concert stage. By repeatedly paying attention to performance cues during practice, the musician ensures that that they become an integral part of the performance, coming to mind effortlessly as the music unfolds. In working memory, they provide the musician with a series of landmarks marking progress through a mental map of the music. The performer remains mindful of these aspects of the performance while allowing others to be executed automatically. When things go smoothly, performance cues are a source of spontaneity and variation in highly polished performances (Chaffin, Lemieux & Chen, 2007). When things go wrong, they provide places at which the soloist can recover and go on.

Performance cues point to different types of memory according to which aspect of the music they address (Chaffin et al., 2002). *Structural* cues are critical places in the formal structure, such as section boundaries. *Expressive* cues represent musical feelings, e.g., excitement. *Interpretive* cues refer to musical gestures, such as changes of tempo or dynamics. *Basic* cues point to motor memory for critical details of technique, e.g., a fingering that sets the hand up for what follows. Musicians are likely to agree on the musical structure of a piece. They are likely to differ, however, on other cues that are more specific to the performer or instrument. For example, basic performance cues for a singer include decisions about breathing that are not relevant for string players. For solo works, the only performance cues required are those for the individual musician, while for ensemble performance the musicians must also establish shared performance cues to coordinate their actions (Ginsborg, Chaffin & Nicholson, 2006).

One way that the location of performance cues can be revealed is by their effects on recall. 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 will fail. The probability of recall, therefore, decreases as distance from the start of the chain increases, resulting in the classic primacy effect in serial learning (Lewandowsky & Murdock, 1989; Roediger & Crowder, 1976).

Two studies have reported primacy effects of this sort in musicians' written recall of the score of music that was memorized for performance (Chaffin & Imreh, 2002; Chaffin et al., 2009). Recall was better at section boundaries and at expressive performance cues and declined progressively in the bars that followed, suggesting that structural and expressive performance cues provided the main *landmarks* in the musicians' mental map of the piece. The same studies also found that basic performance cues had the opposite effect. Recall was *lower* at basic cues and increased 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 detail of execution, e.g., fingerings needed to position the hand for what came next.

One possible explanation for lacunae is that attention to details of execution increased the salience of the sensori-motor context. Since this context is largely absent during written recall, recall was poorer (Chaffin & Logan, 2006). This explanation predicts that the negative effect of attention would extend *before* as well as *after* the distracting technical detail. Effects of attention spread evenly in all directions, like a spotlight (Norman, 1968). Spreading of attention has been observed spatially (Eriksen & St. James, 1986; LaBerge, 1983). It seemed possible that that the same effect would happen temporally; that attention would spread evenly from a focal point in time to events before and after. If so, then we would expect negative effects of attention to diminish with distance, both *before* and *after* a focal point of attention in a musical score .

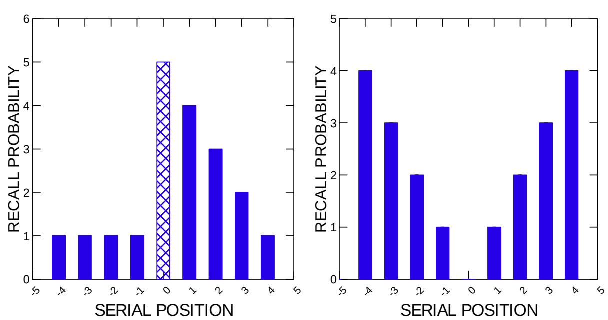

Figure 1. Predicted probability of recall at landmarks (left panel) and lacunae (right panel) as a function of serial position of bars before (SP-before) and before and after (SP-after) the point of interest (located at serial position 0 in both panels and hatch in left panel).

Previous studies had only examined serial position effects *after* performance cues. In this study, we examined recall as a function of serial position *before* (SP-before) and serial position *after* (SP-after) points of interest. Figure 1 shows the expected effects of SP-before (negative SP values) and SP-after (positive SP values) for landmarks (left panel) and lacunae (right panel). The left panel shows a sharp increase in recall probability at bars containing landmarks as content addressable access at a structural or expressive cue provides renewed access to memory. Serial cuing of the following bars results in a stepwise decrease in the bars after a landmark. The right panel shows the stepwise decrease and increase in recall expected before and after lacunae as attention is progressively drawn towards some sensori-motor detail reported as a basic performance cue.

A second purpose of our study was to obtain repeated recalls of the same piece. We hoped that repeated recalls would provide a more reliable measure of memory than a single recall. We also expected to observe a progressive decline in memory over time (Bahrick, 1994), and that landmarks would emerge more clearly as gaps in memory increased.

METHOD

Learning the *Ricercar*

Jane Ginsborg, the second author, is a former professional singer. On 16 December, 2003, she performed as solo soprano in a public performance of Stravinsky's *Cantata* for two solo singers, women's choir and small instrumental ensemble. She had performed the piece once before, more than 25 years earlier, and had not looked at it in the interim. The *Cantata* includes one movement for solo soprano and ensemble, *Ricercar 1,* that was the subject of this study. The *Ricercar* lasts about 4 minutes and consists of 250 beats, scored in 71 bars that alternate intermittently between 3:4 and 4:4 meter.

The singer prepared the *Ricercar* for performance starting in mid-November in five individual practice sessions lasting 4 hours 13 minutes, four joint rehearsals with the conductor lasting 2 hours 47 minutes, and three ensemble rehearsals lasting 57 minutes (Ginsborg, Chaffin & Nicholson, 2006). Practice from memory began in Session 2. The proportion of practice done 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.

Recall

The singer recalled the piece from memory nine times, writing down 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 (FR1) between the last two rehearsal sessions in December, 2003, as part of her normal preparation for the public performance. Three more recalls, between January 2004 and February 2005, yielded only one or two trivial errors and we will not report these data. The next time that the singer made a substantial number of errors was 18 months after performance, when she recalled the piece in June 2005 (FR2). We will report data for this and the four subsequent recalls in August 2006, June 2007, November 2007 and November 2008 (FR3-6). 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 FR1, recalls occurred 18, 32, 42, 47 and 59 months after the public performance. The time intervals since last consulting the score were 4, 10, 6, 5, and 4 months for FR2, FR3, FR4, FR5 and FR6 respectively.

Each beat was scored as correct if words, pitch, and rhythm were all recalled and as incorrect if any error was made.

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 which they were aware of using during the performance as memory (performance) cues. They made their reports by annotating copies of the score, using multiple copies. The two musicians then compared their reports in order to identify *shared performance cues* to which they had consciously attended during the performance and which they knew that the other would be attending to (see Ginsborg et al., 2006 for details).

Table 1 lists the seven types of performance cue and six types of features reported, showing the number of reports of each type and their classification as structural, basic, interpretive, or expressive.

Table 1. Singer's reports of features, individual performance cues (PC) and performance cues shared with the conductor (SPC) with the number of locations reported for each.

Type of PC/feature	Description of Report	# reports
	Performance Cues	
Structural	Start of section	9
	Switch	7
	Start of phrase	28
Basic PC	Prepare	20
	Technical (including breath)	14
Interpretive PC	Stress on words (pronunciation/meaning)	28
Expressive PC	Expressive	12
Basic SPC	Score SPC (entry, ordinate rhythm, cadence)	11
	Arrival/off SPC	8
	Features	
Basic	Prepare (count, listen, think, watch)	35
	Basic words (pronunciation)	25
	Breath/technical	45
Interpretive	Words (interpretation i.e. meaning)	29
	Dynamics/tempo	9
Expressive	Expressive	15

Serial position was coded starting at the beat where the report was marked, which was assigned the serial position "0". Any beats that followed in the same bar were also coded "0". Beats in the same bar that preceded a report were assigned the serial position "1". Serial positions before and after this bar were then assigned by bar. Each bar was numbered successively 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.

Three predictors were created for each type of report: serial position before (SP-before), after (SP-after), and both before and after (SP-before/after). Effects of SP-after would indicate landmarks (Figure 1, left panel), in which case no effect of SP-before was expected. Effects of SP-before/after would indicate lacunae (Figure 1, right panel).

RESULTS

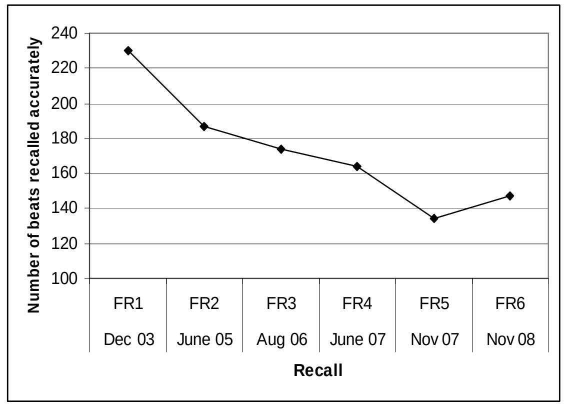

Figure 2. Number of notes recalled accurately (no errors of any kind) over time.

Accuracy of recall declined steadily over time from 92% at the first free recall (FR1) to a low of 54% at the fifth recall (FR5) 47 months later (see Figure 2). The change was statistically significant (F [5, 1245] = 36.42, $p < .0001$).

Landmarks

Starts of phrases were landmarks. In Figure 3 the right panel shows the effect of SP-after; the mean probability of correct recall was highest at the start of a phrase and declined in stepwise fashion in succeeding bars. All effects of serial position were tested with mixed hierarchical regression analyses. The effect of SP-after was significant (*estimate* = -0.0640, *SE* = . 012, Z =-5.236, $p < 0.001$). In contrast, the effect of serial position in bars before the start of a phrase (left panel; SP-before) was not significant. (The numerical values shown in Figure 3 for SP-before and SP-after are those used for these predictors in the analyses. In subsequent graphs we will show SP-before and SP-after in the same panel as in Figure 1).

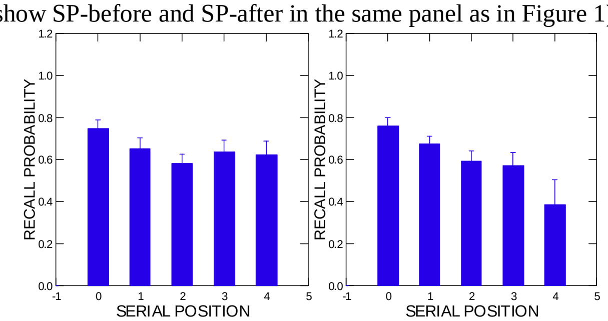

Figure 3. Starts of phrases: Recall probability as a function of SP-before (left panel) and SP-after (right panel). SP = 0 for first bar in a phrase in both panels.

Starts of sections were also landmarks. Figure 4 shows mean recall probability in the bars before and after starts of sections. In this figure, serial positions runs successively from left to right with starts of sections in the middle with a serial position of '0" marked by hatching. Thus, serial positions before (SP-before) are on the left, coded with negative values, and serial positions after the start (SP-after) are on the right with positive values. As with phrases, there was an effect of SP-after (*estimate* = -0.0450, *SE* =.011, Z -4.267, $p < 0.0001$), while the effect of SP-before was not significant.

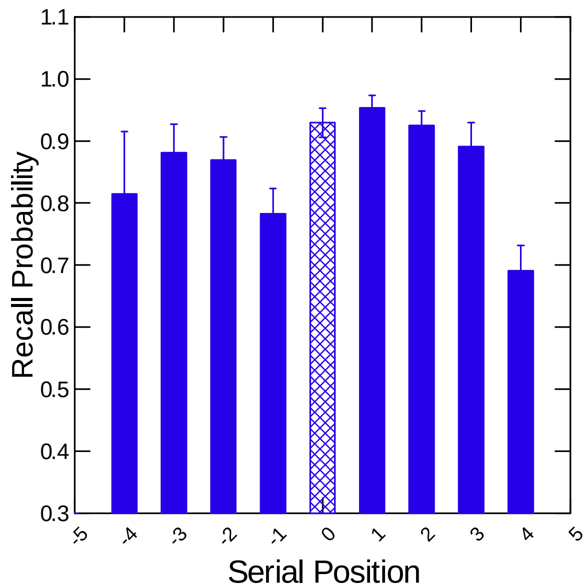

Figure 4. Starts of sections: Recall probability as a function of SP-before (negative SP's) and SP-after (positive SP's). Hatching indicates the location of the first bar in the section (SP=0). Bars are ordered sequentially from left to right.

The effects of phrases and sections correspond closely to the predicted effect of content addressable access shown in the left panel of Figure 1. They suggest that the increase in recall was due to the presence of retrieval cues at the beginnings of phrases and sections. These cues provided content addressable access, allowing the singer to recall these bars even when she was unable to recall the bars immediately before them. Serial cuing of the following bars then resulted in steadily decreasing recall until the next content addressable cue was encountered.

Additional landmarks were provided by performance cues for words (see Figure 5). This is suggested by the sharp jump in recall at these cues (hatched), which was reflected in significant linear and quadratic effects for SP-before (linear, $Z = -5.46$, $p < 0.000$; quadratic, $Z = 2.25$, $p < 0.02$). In this case, the decline in recall after the cue seen in Figures 3 and 4 did not occur until four bars after the cues resulting in significant linear and quadratic effects for SP-after (, $Z = -2.11$, $p < 0.03$; quadratic, $Z = 2.20$, $p < 0.05$). We speculate that thinking about the pronunciation of the particular word marked as the performance cue led the singer to also think about the following words, resulting in superior recall that extended over three bars.

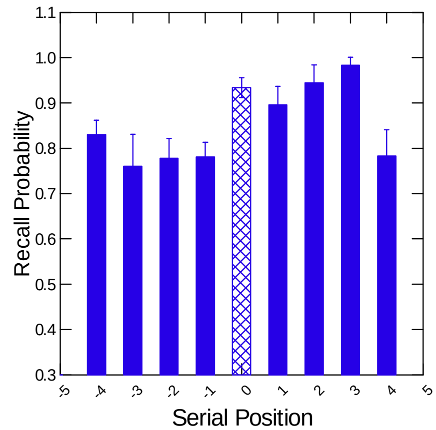

Figure 5. Interpretive PC's for words: Expressive features: Recall probability as a function of SP-before (negative SP's) and SP-after (positive SP's). Hatching indicates the location of the bar containing the interpretive PC (SP=0).

Lacunae

Places where the singer reported features for preparation were lacunae. Figure 6 shows that recall was lowest in bars where the singer reported preparation features and improved symmetrically in both directions as distance from the feature increased. The effect is striking in its symmetry. Bars *before* and *after* the cues were affected in the same way, unlike the effects we have examined so far. The effect of SP-before/after was significant (*estimate* = -0.0780, *SE* . 01116, *Z* =6.802, $p < 0.0001$**)**. There was a similar effect for performance cues for preparation and no significant interaction between the effects for features and cues. The performance cues were the subset of preparation features that need attention during in performance. In this case, the greater importance of the cues had no effect on memory.

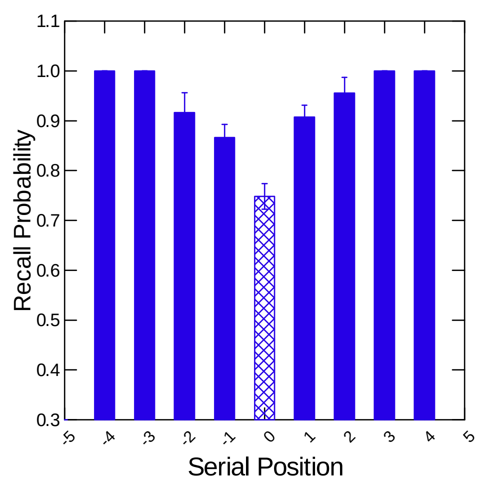

Figure 6. Prepare features: Recall probability as a function of SP-before (negative SP's) and SP-after (positive SP's). Hatching indicates the location where the singer reported that preparation was required (SP=0).

Two considerations suggest that the effect was due to attention. First, the singer reported preparation features at places where she needed to think about her next entry, count beats, listen to the instrumentalists, or watch the conductor.

During practice she counted beats in these places, rather than actively imagining the music. It is not surprising, therefore, that her memory for these passages would be weaker. What is surprising is the scope and systematic nature of the effect, extending across two bars on either side of the passage where the counting was required. This is the second reason for thinking that the effect was due to attention: The symmetry of the effect on either side of the critical bar, diminishing with distance, exactly as would be expected if attention functioned like a spotlight (LaBerge, 1983). To our knowledge, this is the first time that a serial position effect of this type has been reported for recall of any kind of materials.

Other Effects of Attention

There were other cases where effects appeared to be due to attention, but where the effect of attention was to improve memory rather than to impair it. We will report two here. Recall was better at expressive features; the same effect also occurred at expressive performance cues (see Figure 7). Unlike the positive effects we have examined previously, these did not start with the sudden jump in recall that is the hallmark of content addressable access. Instead, there was a stepwise increase extending from three bars before the expressive feature or cue and continuing until the bar after it. The linear increase in recall across these bars was significant (*estimate* = -0.0470, *SE* = . 010, *Z* =-4.625, $p < 0.000$). Inspection of Figure 7 indicates that the S-shaped curve of the effects was very similar for features and performance cues but more exaggerated for performance cues; this difference produced a significant interaction between the two effects (*estimate* = -0.025, *SE* . 010, *Z* =2.555, $p < 0.01$). This is understandable if the effect was due to attention. It appears that expressive cues were the most important of the expressive features and so they received more attention, resulting in a more extreme effect.

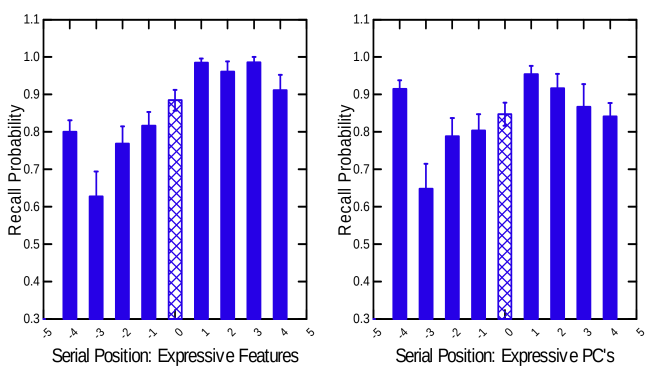

Figure 7. Expressive features: Recall probability as a function of SP-before (negative SP's) and SP-after (positive SP's). Hatching indicates the location of the bar containing the expressive feature (SP=0).

Expressive features and cues directed the singer's attention to places where she needed to convey a particular mood e.g. 'dancing', 'yearning'. We can understand the steady increase in recall in the three bars before the cue as an effect of the spotlight of attention being focused on the upcoming change in expression resulting in decreased attention to the musical material preceding it. Attention may also explain why recall was best in the bar *after* the cue. The singer reported expressive features and cues at places where she was about to convey the new mood; her attention was apparently focused on the bars following the cue where the new mood took effect.

Recall of shared performance cues for arrival/off showed the upward jump in recall at the performance cue that we have identified as the hallmark of content addressable access (see Figure 8). However, in the bars following the cue the stepwise decrease in recall that we attributed to serial cuing was absent, replaced instead by an abrupt drop. The effect of SP-before was significant (linear, $Z = 2.94$, $p < 0.003$; quadratic, $Z = -2.76$, $p < 0.006$), as was that of SP-after ($Z = -3.90$, $p < 0.000$; quadratic, $Z = 3.64$, $p < 0.000$).

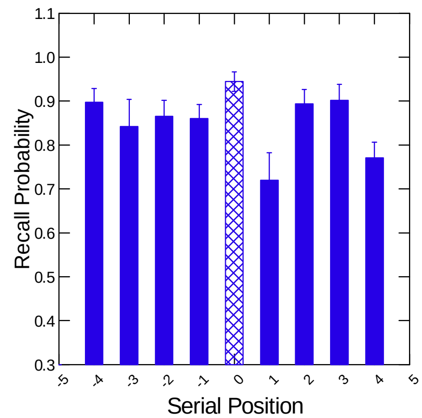

Figure 8. Shared performance cues for arrival/off: Recall probability as a function of SP-before (negative SP's) and SP-after (positive SP's). Hatching indicates the location of the point of interest (SP=0).

We can understand this pattern as a product the singer's attention. Singer and conductor had agreed that it was important for the ensemble to arrive at these places together and "come off" together. Apparently, the importance of coming off together distracted the singer's attention from the bar that followed which was, as a result, more likely to be forgotten.

CONCLUSION

The serial position effects for phrases, sections, and performance cues for words suggest that these were the main landmarks of the singer's memory: places where she had content addressable access to her memory for the piece. Once successfully recalled, the music serially cued memory for what came next until, at some point, a link failed and the chain was broken. The result was the stepwise decrease in recall characteristic of the primacy effect (Roediger & Crowder, 1976). The same stepwise decrease in recall after important musical landmarks has been previously observed in two case studies in which performers wrote out a score from memory many months after a performance (Chaffin & Imreh, 2002; Chaffin et al., 2009). What is new in our study is the identification of the sharp increase in recall preceding the stepwise decrease. We have proposed that this increase is the hallmark of content addressable retrieval.

Shared performance cues for arrival/off, in contrast, were lacunae: places where memory was worse than in other locations. Again, a similar effect has been observed before for basic performance cues (Chaffin & Imreh, 2002; Chaffin et al., 2009). What is new in our study is the identification of the effect as extending symmetrically before and after the performance cue.

The symmetrical effect of lacunae was very different from the asymmetric effect of landmarks, leading us to propose a different type of explanation. We believe that the effect of lacunae is due to the musician's attention being drawn to other aspects of the situation at these points during practice. As a result, we propose, the musician pays less attention to the music and is less able to recall the pitch and duration of the notes. In the present study, we suggest that this happened when the singer's attention was drawn to the other performers. In previous studies, similar decreases in recall after a cue were found at places where the musicians' attention was drawn to details of technique such as fingering or bowing (Chaffin & Imreh, 2002; Chaffin et al., 2009).

We have suggested that the effects of landmarks were due to content addressable access followed by serial cuing. Is it possible that attention could provide an alternative explanation for these effects as well? Landmarks are surely recalled better because they receive more attention. The effect of attention, however, is to establish these places as starting points. To have content addressable access to a passage is to be able to start there, whether in writing out the score or in performing. It is beyond the scope of this paper to report the data for the singer's practice sessions. However, experienced musicians do use important musical boundaries as starting places during practice (Chaffin & Imreh, 2002; Chaffin et al., 2009) and the same was true in the present study (Ginsborg & Chaffin, 2009). Starting at a location establishes the connection between thought and action that is the characteristic of landmarks. Attention to landmarks results in content addressable access and it is this access that is responsible for the characteristic jump in recall.

Landmarks and lacunae are not the only types of serial position profiles possible. We have described two others: for expressive features and shared performance cues for arrival/off. We propose that the serial position profiles for the recall of different kinds of musical features and cues depends on how the musician directs attention during practice. Serial position effects in written recall thus provide a window into the musician's thinking during practice.

It remains for future research to determine whether the effects that we have reported here occur with other musicians. There is every reason to expect that they will. We have already noted that serial position effects have been reported previously for bars *after* points of interest in a piece of music (Chaffin & Imreh, 2002; Chaffin et al., 2009). We found similar effects in the present study. There is every reason to believe that the effects that we have reported here for serial positions *before* points of interest were also present in those earlier studies.

More generally, we believe that most experienced performers memorize in much the same way, with only superficial differences due to music, instrument, and learning style. Musicians' use of musical structure as a retrieval organization and of performance cues as retrieval cues is consistent with general principles of human memory derived from the study of other kinds of experts and of the general population (Chaffin & Logan, 2006; Ericsson & Oliver, 1989). There is good reason to expect that the present findings will generalize to other experienced performers.

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