

How memory fades: Very-long-term recall of Bach

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A cellist memorized the *Prelude* from J. S. Bach's *Suite No. 6* for solo cello and identified performance cues (PCs) that she attended to in performance. During the next three years, she recalled the piece twice, playing and writing out the score from memory on both occasions, in counterbalanced order. Played recall was better than written recall. Written recall was better at expressive and structural PCs, suggesting that these cues provided content accessible access to declarative memory. Written recall was worse at PCs for basic technique but less so when written recall followed played recall. In written recall, serial cuing was impaired by the absence of sensorimotor cues, particularly at basic PCs. These directed the cellist's attention to her actions. Reinstating sensorimotor memory by playing through the piece reduced the impairment caused by the absence of these actions during written recall.

Keywords: music; performance; memory; cello; recall

The demands placed on memory during solo performance in Western art music are extraordinary. Not surprisingly, memory and attentional lapses are not uncommon. Thus, when preparing for a memorized performance, it is important for musicians to develop a memory retrieval system that is flexible and that will permit the performance to proceed whatever may go wrong (Chaffin *et al.* 2002, Lehmann and Ericsson 1998). During music performance, memory for what comes next is normally activated by *serial cuing* as the current passage cues motor and auditory memory (Chaffin *et al.* 2009a). Serial cuing has the limitation that the chain of cues starts at the beginning of the piece so that if the performance is disrupted the musician must start over. For this reason, experienced performers usually prepare an alternative memory retrieval system that provides *content addressable* access, allowing the

musician to recall any passage in the piece by simply thinking of it (e.g. the “G section”). Content addressable access is provided by *performance cues* (PCs) representing landmarks in the music that the performer is able to think about consciously during performance. PCs provide a mental map of the music that allows the performer to monitor the performance as it unfolds and to recover from mistakes and memory lapses.

Written recall of the score has proved an important source of evidence that PCs provide content addressable access to memory (Chaffin and Logan 2006, Chaffin *et al.* 2009b). Recall is better at PCs representing musical expression and structure and declines in the bars that follow (an effect of serial position). This pattern suggests that musicians have content addressable access to memory at these points and then retrieve the following bars by serial cuing. In contrast, recall is poorer at PCs representing decisions about basic technique. One possible explanation is that musicians attend more to details of technique at these points and so pay less attention to the notes. We tested this explanation by comparing written and played recall of a well-prepared piece. We have reported elsewhere that the *written* recall was better at structural and expressive PCs and poorer at basic PCs (Chaffin *et al.* in press). Here we ask whether the same effects occurred when the musician *played* the piece at around the same time.

METHOD

Participants

Tânia Lisboa, the cellist and first author was trained in classical cello and piano in Brazil, England, and France and currently lives in London performing as a cello soloist.

Materials

The *Prelude* from J. S. Bach’s *Suite No. 6* for solo cello explores both the mellow quality and virtuoso aspects of the instrument. The cellist had never learned the *Suite No. 6* for performance before, although she was very familiar with it and had played other works by Bach throughout her career. Written for an instrument with five strings, *Suite No. 6* presents contemporary cellists with substantial technical challenges, as fingerings and left-hand positions must be adapted to play the notes written for the fifth string on the four strings of a modern cello. Musically, however, the *Prelude* is comparable to the other five Bach cello suites. Notated in 104 bars in $12/8$ time, the piece takes about five minutes to perform.

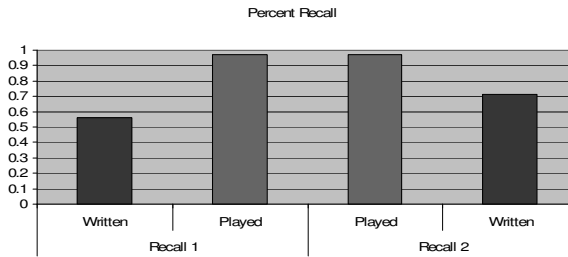


Figure 1. Percentage correct on two tests of written and played recall, shown in temporal order from left to right.

Table 1. Regression coefficients for the effects of serial position of half-bars from PCs on probability of correct recall for first/second written recalls.

<i>Effect of serial position following</i>	<i>Effects</i>	<i>Interaction indicating difference between recall tests</i>
Expressive PCs	-0.073*	0.033
Structural PCs	-0.032	0.025
Interpretive PCs	0.031	-0.007
Basic PCs	0.086**	-0.050*
Structural PCs × Expressive PCs	-0.018*	

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Procedure

The cellist learned the *Prelude* for a series of eight public performances. She then provided reports about the musical structure and PCs she attended to during performance (expressive, interpretive, intonation, and basic technique) as part of another study (Chaffin *et al.* in press). Written and played recall were each tested twice in counterbalanced order. The first test began ten months after the last public performance with the cellist writing out the score from memory. She then played it from memory seven weeks later, recording her playing. Twenty months later, she began the second test by playing the piece from memory again, and then wrote it out for a second time four weeks later. She did not otherwise play or study the piece during this time. Written and played recall were scored for accuracy.

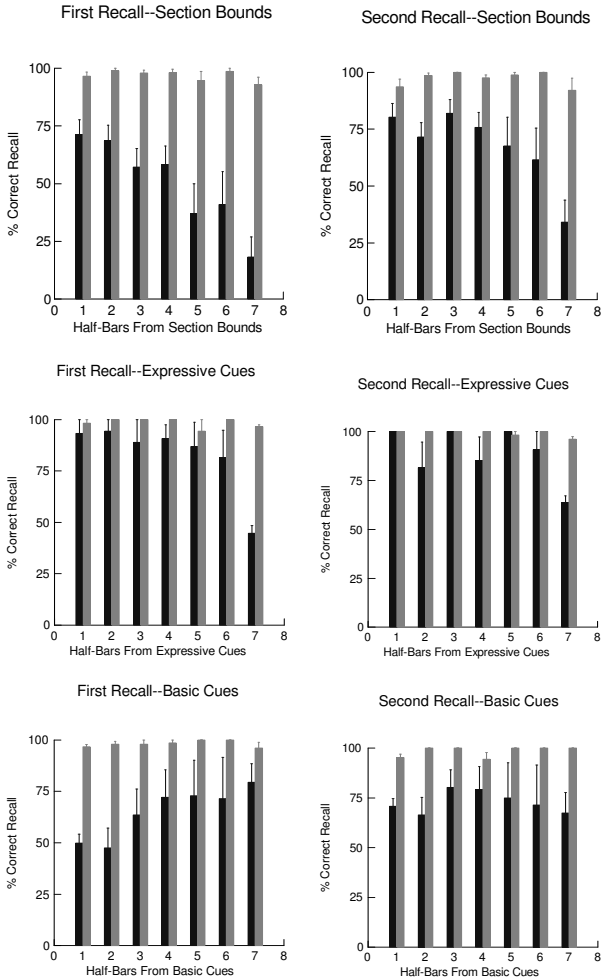


Figure 2. Mean probability of correct recall [written (black) and played (grey)] as a function of serial position of half-bars numbered sequentially from beginnings of sub-sections (structural PCs), expressive PCs, and basic PCs for first/second recall tests.

RESULTS

Recall was almost perfect for the two played tests and substantially lower for the two written tests (Figure 1). The difference demonstrates the large role

played by motor and auditory memory. Written recall was better (71%) in the second round of testing than in the first (56%).

Table 1 summarizes the results of a mixed hierarchical regression analysis testing the effects of serial order and their interaction with the first and second set of tests. For beginnings of sub-sections and expressive PCs, recall declined as distance increased (see Figure 2, top and middle panels, respectively). For basic PCs, the effect was in the opposite direction—probability of recall was lowest at basic PCs and increased with distance—and was larger on the second test (see Figure 2, bottom panels).

DISCUSSION

The cellist's ability to play almost without error after more than two years of not playing or thinking about the music is notable. The cellist described the experience in an email to the second author shortly afterward:

It is awful to play without having practiced the piece for so long because, besides memory, the hands feel soggy and I have no technical control of anything even when I remembered it. I...was hesitating all the way through but managed to get to the end. At some places...my fingers seemed to go by themselves.... Mostly, it was thinking of bowing and fingering (basic PCs) that...got me through.

At the end of this account, she points to the importance of the sensorimotor cues created by her playing, which provided effective serial cuing of her actions, even in the absence of any declarative memory for what came next.

Sensorimotor cues were important to both played and written recall. The reduction in sensorimotor cues in written recall explains why (1) written was worse than played recall, (2) written recall was worse on first test than on the second, and (3) written recall was worse at basic PCs. First, written recall was worse than played recall because it provided fewer sensorimotor cues for what came next. Second, written recall was better on the second test than the first, despite the passage of two years, because the cellist had recently refreshed her sensorimotor memory by playing the piece in the played recall test four weeks earlier. Third, written recall was worse at basic PCs because they directed the cellist's attention toward her actions and away from the music when learning the piece, so that in recalling it, she relied more heavily on cuing by the sensorimotor context. In written recall, the absence of the sensorimotor context provided by her playing had a bigger impact at basic PCs because she relied more heavily on these contextual cues at these points.

Thus, basic PCs operated as part of the serial chain of associations that reminded the musician of what came next (Chaffin *et al.* in press).

Structural and expressive PCs, in contrast, provided content addressable access to the cellist's declarative memory, allowing her to recall a passage simply by thinking of it. Direct access to these landmarks in memory produced better recall by allowing the cellist to recover and to begin writing again after gaps in her memory where she was unable to recall anything. Once begun, the memory of each passage cued recall of what followed until, at some point, a link failed and the chain was broken, resulting in a poorer recall as distance from the landmark increased (Roediger and Crowder 1976).

The results for the second written recall replicated the previously reported finding that her recall was better at expressive PCs than at the beginnings of subsections (Chaffin *et al.* in press). The difference supports the idea that expressive PCs marked the highest level in the cellist's hierarchical organization of the music into harmonic sections (marked by expressive PCs) and melodic subsections. By contrasting played and written recall, this study has increased our understanding of how basic PCs differ from other kinds of PCs.

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