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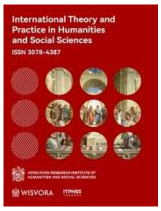

From Cognitive Memory to Self-Regulation: A Multidimensional Pathway to Stable Musical Score Memory

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Abstract

This review proposes an integrative theoretical framework that explains the development of stable musical score memory as a function of both cognitive architecture and self-regulatory processes. Grounded in the multiple memory systems theory and the three-phase self-regulated learning (SRL) model, the framework conceptualizes musical memorization as a dynamic, recursive process involving the selective activation and coordination of five long-term memory systems—semantic, emotional, perceptual, procedural, and narrative—across the SRL phases of forethought, performance, and reflection. Drawing upon recent empirical findings in cognitive neuroscience, affective memory research, and metacognitive theory (2021–2025), this review introduces a matrix-based model that maps phase-specific memory activation and regulation mechanisms. The model elucidates how SRL functions as a meta-regulatory system that governs memory system engagement to support goal setting, skill acquisition, expressive performance, and adaptive evaluation. Pedagogical implications include the design of SRL-informed instructional strategies that target memory-specific learning functions, enhance learner autonomy, and improve long-term retention. The review concludes by outlining future research directions involving longitudinal tracking of memory dynamics, neurocognitive measurement of learning phases, and AI-enhanced scaffolding of SRL in music education. By reframing musical memorization as a cognitively distributed and strategically regulated process, this work offers a novel contribution to the interdisciplinary understanding of memory-based performance learning.

1. Introduction

Mastering musical performance from memory is considered one of the most complex and cognitively demanding tasks in arts education. Beyond mechanical repetition or rote learning, the ability to form stable musical score memory reflects a deeper interplay between multiple memory systems—including semantic, emotional, perceptual, procedural, and narrative memory—and learners' capacity for self-regulated learning (SRL). Although each of these domains has been studied extensively in isolation, few efforts have been made to synthesize them into a unified framework to explain how students become autonomous, stable, and expressive performers.

Recent research in semantic memory reveals its crucial role in organizing tonal structure, musical syntax, and conceptual knowledge related to musical elements. Likewise, emotional memory has been shown to enhance retention through affective arousal, contextual binding, and autobiographical significance, with neurocognitive studies mapping its modulation by mood, stress, and sleep (Klune et al., 2021; Anderson & Floresco, 2022; Vrijsen et al., 2023). At the perceptual level, perceptual memory aids in encoding visual and auditory information for fluent score reading and sensorimotor integration, particularly in highly structured visual contexts (Gurguryan et al., 2024; Steel et al., 2024). Procedural memory, supported by repetitive practice and automatized motor routines, is fundamental for performance fluency, but also interacts dynamically with feedback, rest intervals, and hippocampal support (Mylonas et al., 2024; Fioriti et al., 2025). Moreover, emerging evidence suggests that narrative memory supports musical understanding through temporal coherence and meaning construction, linking phrases into "stories" for recall.

Parallel to this, the field of educational psychology has advanced the SRL framework, emphasizing the role of forethought (goal-setting and planning), performance control (strategy use and attention), and reflection (self-evaluation and adjustment) in academic and artistic learning (Brady et al., 2024; Arvatz et al., 2025; Zhu, 2025). While SRL has been applied to music learning (Maimaiti & Hew, 2025), it is rarely aligned explicitly with cognitive memory theories.

This review proposes a multidimensional framework that integrates cognitive memory systems with SRL phases to explain how students independently construct and stabilize musical score memory. Through a systematic synthesis of over 70 recent studies across cognitive science, neuroscience, and music education, this article identifies theoretical intersections, practical implications, and future research opportunities to bridge the gap between memory and metacognitive learning in music.

2. Cognitive Psychology Perspective: Five Memory Systems in Musical Performance

The cognitive processes underlying musical performance from memory extend beyond rote repetition or technical execution. Grounded in the multiple memory systems framework , recent cognitive psychology and neuroscience research has converged on five long-term memory systems that are integral to musical learning: semantic, emotional, perceptual, procedural, and narrative memory. Each system contributes distinct encoding and retrieval mechanisms, with specific neural bases and instructional implications. A detailed synthesis is presented in Table 1.

Table 1. Cognitive Memory Systems in Musical Performance

Memory System	Core Cognitive Function	Neural Correlates	Music-Specific Manifestation	Educational Implications
Semantic Memory	Abstract conceptualization; rule-based retrieval	Medial temporal lobe, anterior temporal cortex, default mode network (Cabalo et al., 2024)	Encoding tonal hierarchy, harmonic progression, form schemas	Encourage analytical rehearsal; use of structural labels and schema mapping
Emotional Memory	Affective salience; context-dependent consolidation	Amygdala, hippocampus, ventromedial prefrontal	Emotional phrasing, autobiographical association, expressive cueing	Align practice with mood; leverage emotional

		cortex (Klune et al., 2021; Anderson & Floresco, 2022)		labeling in interpretation
Perceptual Memory	Sensory detail encoding and sensory cue retrieval	Sensory cortex, hippocampus, ventral visual stream (Heinen et al., 2024; Gurguryan et al., 2024)	Sight-reading, visual/auditory pattern recognition, contour memory	Use slow reading, visualization, multisensory exercises
Procedural Memory	Motor sequence automatization; non-declarative learning	Basal ganglia, cerebellum, motor cortex, hippocampus (Mylonas et al., 2024; Hayward et al., 2024)	Finger sequences, timing fluency, kinesthetic anticipation	Spaced repetition, segmentation, motor-focused feedback loops
Narrative Memory	Temporal ordering; schema-driven episodic construction	Angular gyrus, posterior cingulate, medial prefrontal cortex (Mace et al., 2025; Grob et al., 2024)	Connecting sections as stories, emotional/thematic arcs	Structure rehearsal around narrative arcs; verbalization of expressive intent

2.1 Semantic Memory: Structural Encoding of Musical Knowledge

Semantic memory plays a foundational role in enabling learners to encode, retrieve, and manipulate abstract musical knowledge, such as tonal hierarchies, harmonic progressions, and formal structures. This type of memory allows for the internalization of culturally shared musical syntax, forming the cognitive scaffolding upon which complex musical interpretation is built. Neuroimaging evidence suggests that individuals with well-developed semantic networks demonstrate more efficient access to hierarchical rule structures and stylistic conventions in music, facilitating faster and more accurate score processing (Cabalo et al., 2024).

Building on this, Luchini et al. (2024) found that high-knowledge students exhibit longitudinally stable semantic memory networks, which contribute to enhanced chunking strategies and predictive learning mechanisms during repeated practice. This finding highlights the role of semantic stability in optimizing rehearsal efficiency and cognitive economy. In computational terms, the Global Semantic Memory (GSM) model developed by Li et al. (2025) captures the hierarchical organization of structured domains like music, offering a generative framework for simulating tonal relations and thematic expectations.

Furthermore, Johns (2024) demonstrated that semantic networks are not universally fixed but are instead shaped by individuals' cognitive experiences, musical background, and stylistic exposure. These individualized networks reflect how learners encode musical structures based on prior knowledge and cognitive flexibility. This insight reinforces the pedagogical imperative to cultivate schema-based rehearsal strategies, such as form labeling, functional harmonic analysis, and conceptual mapping. Instructors can thus support semantic memory consolidation by encouraging learners to verbalize structural insights and apply rule-based reasoning, promoting a deeper, more durable internalization of musical syntax.

2.2 Emotional Memory: Affective Modulation of Retention and Recall

Emotional memory plays a crucial modulatory role in determining which musical experiences are encoded with greater durability and accessibility. By prioritizing stimuli with strong affective salience—whether through personal significance or expressive intensity—emotional memory enhances long-term retention and facilitates vivid recall during performance. At the neurobiological level, activation of the amygdala–hippocampal–medial prefrontal cortex (mPFC) circuit has been shown to underlie both the initial encoding and subsequent regulation of emotionally charged material, contributing to more robust memory traces (Anderson & Floresco, 2022). This neural configuration is particularly relevant to music performance, where emotional resonance frequently co-occurs with interpretative depth and expressivity.

Moreover, emotional memory serves as a cognitive anchor in high-pressure situations, providing performers with an affective framework that supports expressive retrieval and performance fluency. Davidson and Pace-Schott (2021) emphasized the role of sleep in consolidating emotional memories, highlighting how nocturnal reprocessing contributes to the stabilization of affective tone and mood congruence in memory. These findings suggest that pre-performance emotional states—regulated through sleep, rest, or mindfulness—can influence the availability and quality of musical recall.

In contextual terms, Vrijsen et al. (2023) demonstrated that emotional congruence between the affective environment of learning and that of retrieval significantly enhances memory precision. For musicians, this suggests that aligning rehearsal affect with anticipated performance conditions—such as intensity, atmosphere, or emotional intention—may facilitate more accurate and emotionally authentic recall. Additionally, Cooper et al. (2023) identified that emotionally charged semantic proxies—such as metaphor, imagery, or programmatic cues—indirectly support memory consolidation through associative encoding. This underscores the pedagogical potential of integrating emotional labeling, narrative association, and personal relevance into rehearsal practices to deepen interpretive memory pathways.

2.3 Perceptual Memory: Multisensory Encoding and Cue Sensitivity

Perceptual memory is responsible for encoding and retaining sensory-specific information, particularly visual and auditory cues that are essential for real-time music reading, pitch contour recognition, and cross-modal sensory integration. It supports the ability of performers to form stable representations of notation patterns, finger placements, and timbral expectations. Unlike abstract semantic processing, perceptual memory anchors learning in the concrete details of sensory experience, making it particularly relevant in the early stages of score acquisition and instrumental technique development.

Recent research underscores the importance of perceptual salience and visual distinctiveness in enhancing memory durability. For instance, Ye et al. (2024) found that visual memorability predicts stronger and more persistent memory traces, especially in complex visual arrays such as musical notation. Lin et al. (2024) further reported that perceptual complexity—defined by visual features that are difficult to reconstruct—contributes to stronger encoding, suggesting that more intricate score materials may paradoxically enhance learning when scaffolded effectively. These findings emphasize the pedagogical value of training students to engage actively with notational subtleties and sensory variance.

Moreover, Cretton et al. (2024) showed that high perceptual load during variable practice routines engages broad cortical networks, including attentional and sensorimotor regions, thereby facilitating generalized improvements in working memory and transferability across contexts. Such results support the integration of structured perceptual challenges into rehearsal design, such as varied tempo sight-reading or altered visual formats, to enhance adaptive encoding. Neurocognitive evidence further validates the role of perceptual memory in musical expertise. Heinen et al. (2024) and Gurguryan et al. (2024) demonstrated that hippocampus-mediated encoding of auditory and visual detail contributes significantly to performance speed and accuracy, especially under temporal constraints. These findings point to the importance of incorporating multisensory strategy training—such as mental imagery, slow reading, and aural replay—into instruction, particularly during the foundational phase of musical development.

2.4 Procedural Memory: Implicit Automatization of Musical Skill

Procedural memory governs the unconscious acquisition and execution of motor sequences, enabling musicians to perform technically demanding passages with fluency, precision, and minimal cognitive load. This implicit system underlies the habitual and kinesthetic aspects of musical expertise, such as fingerings, bowing patterns, pedaling coordination, and articulation consistency. Its efficiency allows cognitive resources to be redirected toward expressive interpretation and real-time musical decision-making.

Traditional views have situated procedural memory predominantly within subcortical structures such as the basal ganglia and cerebellum. However, recent neuroscientific research has begun to nuance this understanding. Mylonas et al. (2024) highlighted that procedural consolidation—particularly during early learning—is enhanced by brief rest intervals, which permit motor routines to stabilize without conscious rehearsal. Furthermore, Della-Maggiore (2024) provided evidence that the hippocampus, long associated with declarative memory, is also activated during the early phases of procedural motor learning, suggesting a dynamic interplay between explicit and implicit memory systems during skill acquisition.

Clinical and applied findings further underscore the vulnerability of procedural memory under adverse conditions. Hayward et al. (2024) demonstrated that patients with long-COVID exhibited deficits in motor memory maintenance, while similar impairments have long been documented in Parkinson's disease. These insights emphasize the need for protective rehearsal strategies that buffer against cognitive fatigue and motor breakdown. From an educational perspective, such evidence supports the implementation of motor-focused practice designs that promote chunking, segmentation, and the use of errorless learning paradigms. Instructors are encouraged to scaffold motor learning with gradual tempo increases, task-specific repetitions, and haptic feedback loops, all of which enhance procedural automatization while minimizing cognitive interference.

2.5 Narrative Memory: Coherence through Temporal Structuring

Narrative memory serves as a higher-order cognitive mechanism that enables the temporal organization and thematic integration of experiences, supporting the construction of meaning across time. In musical contexts, this system allows performers to perceive and reproduce musical works not as isolated notes or sections but as evolving emotional and structural journeys. This capacity is particularly vital in interpreting long-form compositions, where thematic recurrences, developmental arcs, and expressive contrasts must be maintained over extended durations.

Empirical studies suggest that narrative cognition significantly enhances memory encoding and retrieval. Mace et al. (2025) demonstrated that narrative priming—through exposure to temporally or thematically structured stimuli—boosts recall in autobiographical memory tasks. Similarly, Thomsen et al. (2024) found that memory traces anchored in personally salient narratives exhibit greater centrality, durability, and affective weight. These findings align with educational strategies that encourage learners to internalize music as a sequence of expressive episodes rather than discrete technical challenges.

At the neural level, Grob et al. (2024) identified the angular gyrus as a key region facilitating the insight-driven reconfiguration of narrative events, indicating that this area may mediate the flexible reinterpretation of musical meaning across different performance contexts. This mechanism is especially relevant for developing musicians who are learning to move beyond literal score reproduction toward expressive autonomy and interpretive depth.

From an instructional perspective, embedding narrative strategies into practice—such as associating musical phrases with imagined stories, visual scenes, or dramatic personas—can promote structural memory consolidation and emotional engagement. Intermediate learners, in particular, may benefit from being guided to construct internal storylines or "expressive maps" of their repertoire, enhancing both their cognitive coherence and artistic interpretation.

2.6 Theoretical Synthesis: Integration across Systems

From a cognitive systems perspective, the formation of musical memory is best understood not as the function of any single process but as the result of dynamic, interactive engagement among multiple specialized subsystems. Each memory system—semantic, emotional, perceptual, procedural, and narrative—plays a distinct yet interdependent role in encoding, retaining, and retrieving musical knowledge. This multicomponent view aligns with the theoretical model of multiple memory systems (Squire, 2004), which posits that memory is distributed across anatomically and functionally distinct regions of the brain, each optimized for specific types of information processing.

Contemporary network-based approaches further refine this view by emphasizing the integration and coordination among memory systems, particularly during complex tasks such as music performance. The effectiveness of memory retrieval, under this model, hinges not only on the fidelity of individual traces but on the extent to which cross-system coherence is achieved. For instance, emotionally charged passages may be better retained when aligned with semantic schema and reinforced through procedural automatization—demonstrating how synergistic activation enhances memory resilience.

Moreover, working memory, as modeled in Baddeley's multicomponent theory and extended by Berz (1995) into musical domains, plays a pivotal role in the real-time manipulation of information. It serves as a temporary workspace in which perceptual and semantic inputs are integrated, restructured, and transformed into performable actions. This central executive function is especially critical during sight-reading, improvisation, and interpretive rehearsal, where rapid updating and cross-modal coordination are essential.

Importantly, the capacity to orchestrate these memory systems is not innately automatic but develops with experience, deliberate practice, and strategic intervention. The differential ability to coordinate memory subsystems often distinguishes expert performers from novices, particularly in their capacity to retrieve expressive, context-sensitive material under performance pressure. As the following section will explore, this coordination is tightly coupled with metacognitive monitoring and motivational scaffolding—hallmarks of the self-regulated learning (SRL) framework, which provides a theoretical lens for understanding how students can be guided to develop robust and transferable musical memories.

3. Educational Psychology Perspective: The Explanatory Power of the Three-Phase SRL Model

While memory systems provide the foundational architecture for encoding and retrieving musical information, the orchestration of these systems over time depends on self-regulated learning (SRL)—a metacognitive, motivational, and behavioral process that enables learners to take control of their own learning. Rooted in social cognitive theory (Zimmerman, 2000), SRL comprises three recursive and interrelated phases: forethought, performance, and self-reflection. In the context of music education, SRL explains not only how students acquire technical and expressive proficiency, but also how they build and sustain stable, self-initiated musical memory. This section reviews recent research (2021–2025) on each SRL phase and its connection to memory system activation.

3.1 Forethought Phase: Strategic Goal-Setting and Semantic Pre-Activation

The forethought phase represents the preparatory stage of self-regulated learning (SRL), wherein learners formulate strategic intentions and motivational frameworks prior to task engagement. According to Zimmerman's (2000) SRL model, this phase encompasses goal setting, strategic planning, and the activation of self-beliefs, including self-efficacy, task value, and expected outcomes. Within the domain of musical memorization, forethought involves the analytical deconstruction of musical works—such as identifying formal structures, harmonic progressions, expressive markers, and technical demands—prior to the initiation of rehearsal. This proactive planning enables learners to engage their cognitive resources efficiently and with clear purpose.

Empirical evidence underscores the significance of forethought for memory formation in expert musical practice. For instance, dos Santos Silva et al. (2024) observed that professional musicians habitually engage in cognitive rehearsal and phrase-level segmentation before performance, enhancing structural awareness and encoding fluency. Brady et al. (2024) similarly reported that students who consistently applied pre-task planning strategies demonstrated higher levels of self-regulated performance and improved retention. These findings highlight the crucial role of semantic memory, which is invoked to access prior knowledge of tonal grammar and stylistic conventions, as well as narrative memory, which helps frame musical content within emotionally resonant or thematically coherent arcs (Mace et al., 2025; Thomsen et al., 2024; Gu et al., 2025).

The evolution of digital learning environments has further augmented the role of forethought in musical education. Cheng et al. (2024), using multimodal methodologies such as eye-tracking and retrospective think-aloud protocols, found that high-performing students allocate attentional resources more deliberately during early encounters with complex musical passages—indicating active structural anticipation. Arvatz et al. (2025) demonstrated that reflection-enabled planning tools, such as guided rehearsal planners, self-assessment rubrics, and metacognitive journals, reinforce the forethought process by making implicit planning behaviors explicit and trainable.

Crucially, the forethought phase also preconditions the involvement of emotional memory by allowing learners to mentally simulate expressive intentions and align their affective states with anticipated performance goals. Through such cognitive-emotional priming, learners not only structure their rehearsal sessions more strategically but also increase the likelihood of deeper and more durable encoding. This interplay of motivation, planning, and memory system pre-activation lays the foundation for the subsequent phases of performance and self-reflection in SRL.

3.2 Performance Phase: Real-Time Monitoring and Procedural Engagement

The performance phase of self-regulated learning (SRL) represents the execution stage, where learners translate strategic plans into real-time behavior. This phase involves not only the implementation of techniques but also continuous cognitive and metacognitive regulation—such as maintaining attentional focus, adjusting tempo, detecting errors, and modulating expression. In musical contexts, it is during this phase that the interplay between procedural, perceptual, and emotional memory systems becomes most salient, enabling the learner to sustain technical fluency while simultaneously interpreting expressive intent.

Metacognitive self-monitoring lies at the heart of this phase. McPherson et al. (2019), through microanalytic studies of practice behavior, found that students who verbalized their self-monitoring and consciously segmented their practice routines achieved greater retention and expressive consistency. These findings reinforce the view that procedural automatization does not arise passively, but through deliberate iteration guided by self-awareness. In this regard, procedural memory—anchored in motor patterning and reinforced by distributed, spaced repetition—is optimized when learners integrate real-time feedback and error correction (Mylonas et al., 2024).

Technological scaffolds have also proven beneficial in reinforcing SRL processes during performance. Maimaiti and Hew (2025) demonstrated that gamified practice environments, which incorporate immediate feedback and motivational reinforcement, significantly increased learners' persistence and accuracy across sessions. These digital tools appear to support both procedural engagement and perceptual memory activation by heightening learners' sensitivity to auditory and visual feedback—an observation supported by neurocognitive research (Ye et al., 2024; Heinen et al., 2024).

Importantly, affective states also shape performance-phase outcomes. The emotional memory system, particularly the amygdala–hippocampal–mPFC network, modulates attention, salience tagging, and stress regulation during execution. Vrijsen et al. (2023) demonstrated that emotional congruence between practice and recall contexts enhances retrieval fidelity. Cooper et al. (2023) further showed that emotionally salient cues can generalize across contexts, improving memory consolidation through medial temporal lobe interactions. These findings suggest that effective rehearsal environments must balance cognitive control with emotional attunement—encouraging students to engage not only technically, but affectively, with the musical material.

so, the performance phase is not simply about enacting previously learned content, but about adaptive regulation in real time. Successful musicianship depends on the ability to manage attention, monitor feedback, and integrate multisystemic memory cues—all while remaining expressive and resilient under cognitive load. It is this active integration that distinguishes surface-level repetition from deep, transferable learning.

3.3 Self-Reflection Phase: Metamemory, Attribution, and Emotional Reframing

The self-reflection phase is the culmination of the self-regulated learning (SRL) cycle, wherein learners engage in metacognitive evaluation to assess the effectiveness of their strategies, interpret outcomes, and inform future actions. This phase involves key cognitive components such as judgment of learning (JOL), self-appraisal, and attributional reasoning, which together contribute to the refinement of learning habits and the internalization of performance-related knowledge. Unlike the more execution-oriented performance phase, reflection re-engages emotional, semantic, and narrative memory systems in the service of integrative, meaning-making processes.

A central element of this phase is metamemory accuracy—the ability to judge one's memory reliability and learning progress. Lund et al. (2025) found that individuals with high cross-domain metacognitive ability (spanning perception, semantic memory, and episodic memory) also demonstrated superior SRL outcomes. In musical contexts, this translates into learners accurately evaluating their expressive and technical execution. McPherson et al. (2019) showed that students who engaged in systematic self-evaluation—such as identifying phrasing inconsistencies or articulation flaws—were more consistent in their memorization and demonstrated improved performance reliability over time.

Emotions also play a pivotal role in reflective processing. The emotional memory system, particularly its affective tagging and consolidation functions, influences how learners interpret their performance experiences. dos Santos Silva et al. (2024) observed that feelings of emotional satisfaction or frustration serve as cues that either deepen or inhibit reflective engagement. These findings align with Davidson and Pace-Schott (2021), who showed that emotional tone is modulated and stabilized by sleep, thus affecting the depth of post-practice consolidation. Learners who experience high affective resonance with their performance are more likely to encode that experience narratively, integrating it into a larger self-concept of musical growth.

Technologically mediated environments are increasingly supporting this reflective capacity. Zhu (2025) demonstrated that tools such as ChatGPT, when embedded into structured SRL cycles, enhance the depth and specificity of students' reflections, particularly in asynchronous learning contexts. Likewise, video-based self-review platforms and interactive SRL dashboards (de Vreugd et al., 2025) provide externalized representations of performance, facilitating more objective self-assessment and encouraging data-informed strategy revision. These tools amplify learners' capacity to identify trends, adjust approaches, and engage in causal attributions grounded in evidence rather than affective volatility.the self-reflection phase fosters narrative coherence, as learners begin to weave their successes and challenges into temporally structured, emotionally meaningful progressions. Thomsen et al. (2024) found that the narrative centrality of personal experiences predicts their memorability and self-relevance, reinforcing the pedagogical value of helping students frame practice episodes as part of evolving musical identities. By doing so, reflection becomes not merely corrective but constructive, enabling students to reconceptualize errors as growth opportunities and to strengthen motivational alignment for future learning.

3.4 SRL as a Meta-Regulatory Framework over Memory System Activation

Self-regulated learning (SRL) operates not merely as a sequence of cognitive events, but as a recursive, adaptive, and hierarchical control mechanism that modulates the activation of memory subsystems in response to evolving task demands. Rather than proceeding in a fixed linear order, the three SRL phases—forethought, performance, and self-reflection—interact dynamically. Each phase selectively engages and coordinates distinct memory systems to optimize learning efficiency and retention.

During the forethought phase, learners activate semantic memory networks to retrieve domain-relevant schemas and invoke narrative memory to impose structural coherence on upcoming tasks (Gu et al., 2025; Mace et al., 2025). This anticipatory engagement lays the groundwork for encoding by priming meaningful associations and organizing complex material into retrievable units.

In the performance phase, perceptual and procedural systems take precedence. Perceptual memory supports the recognition and processing of sensory input, such as visual notation and auditory cues, while procedural memory governs the fluid execution of motor sequences (Heinen et al., 2024; Mylonas et al., 2024). These processes are monitored and adjusted in real-time through metacognitive control, enabling learners to detect errors, modulate expressive nuance, and maintain attentional focus.

The self-reflection phase re-engages emotional and narrative memory to evaluate outcomes and reframe experiences. Emotional feedback helps encode performance episodes with affective salience, while autobiographical narrative structures integrate these experiences into long-term memory, shaping future learning attitudes and strategy use (Davidson & Pace-Schott, 2021; Thomsen et al., 2024).

This systemic interaction is empirically supported. Latva-aho et al. (2024) demonstrated that pre-service teachers who conceptualized SRL as a memory-regulatory process—not just a behavioral scaffold—were more effective in facilitating student strategy transfer and adapting instruction to cognitive variability. Such findings suggest that SRL serves as a top-down meta-regulatory architecture, orchestrating bottom-up memory activations according to context and task constraints (Zimmerman & Moylan, 2009).

Consequently, the development of robust, expressive, and context-sensitive musical memory does not depend solely on the strength of individual memory traces. Instead, it hinges on the learner's capacity to govern the timing, coordination, and intensity of memory system engagement. As the following section will outline, a multidimensional mapping of memory activation across the SRL continuum offers both explanatory clarity and instructional leverage—clarifying how targeted interventions can foster expert-like memorization in music education.

4. The Integrated Model of Memory Systems × Self-Regulated Learning Phases

The formation of stable musical score memory is not a product of isolated memory functions, but of a dynamically regulated system in which cognitive memory subsystems are selectively activated, modulated, and consolidated through self-regulated learning (SRL) processes. Building upon the foundations of multiple memory systems theory (Tulving, 1985; Squire, 2004) and Zimmerman, B. J. (2000)SRL framework, this section proposes an integrative model that maps the interactions between long-term memory systems and SRL's three recursive phases: forethought, performance, and self-reflection. The Memory × SRL Activation Matrix synthesizes findings from cognitive neuroscience, educational psychology, and music pedagogy to illuminate the phase-specific activation of semantic, emotional, perceptual, procedural, and narrative memory in expert and developing musicians.

4.1 Mapping Cognitive-Metacognitive Interaction: The Matrix Model

As shown in Table 1, each memory system supports distinct cognitive demands across SRL phases. Rather than operating in isolation, memory subsystems are co-activated and regulated hierarchically in a way that reflects the adaptive goals and contextual constraints of the learning phase (Cabalo et al., 2024; Heinen et al., 2024). The matrix thus represents an executive control map, where SRL functions as a top-down agent directing bottom-up memory operations. This model is supported by recent theoretical advances in distributed cognition and domain-general metacognitive regulation (Lund et al., 2025), as well as empirical microanalytic SRL studies in music education (dos Santos Silva et al., 2024).

Table 1. Memory Systems × SRL Phases: Phase-Specific Activations

Memory System	Forethought Phase	Performance Phase	Reflection Phase
Semantic Memory	Structural Analysis	Schema Retrieval	Metacognitive Review

	(Semantic-Dominant)	(Semantic-Support)	(Semantic-Support)
Emotional Memory	Affective Goal Framing (Emotional-Support)	Expressive Modulation (Emotional-Dominant)	Emotional Attribution (Emotional-Dominant)
Perceptual Memory	Sensory Cue Preparation (Perceptual-Support)	Auditory/Visual Integration (Perceptual-Dominant)	Cue Reconstruction (Perceptual-Support)
Procedural Memory	Motor Planning (Procedural-Support)	Automatic Execution (Procedural-Dominant)	Motor Feedback Evaluation (Procedural-Support)
Narrative Memory	Narrative Structuring (Narrative-Dominant)	Expressive Enactment (Narrative-Support)	Self-Narration (Narrative-Dominant)

4.2 Phase-Specific Memory Activation

Forethought Phase. In this anticipatory phase, learners engage in strategic goal-setting, mental representation, and motivational calibration (Zimmerman, 2000). Semantic memory is activated to analyze musical form and structure (Gu et al., 2025; Luchini et al., 2024), while narrative memory assists in organizing musical content into story-like frameworks (Thomsen et al., 2024). Emotional memory contributes by framing personal meaning and affective commitment to learning goals (Vrijsen et al., 2023).

Performance Phase. Learners engage procedural memory for automated execution of motor patterns (Mylonas et al., 2024) and perceptual memory to manage real-time visual and auditory information (Steel et al., 2024). Emotional modulation enhances expressive fidelity and retrieval robustness (Davidson & Pace-Schott, 2021).

Reflection Phase. Learners draw upon semantic memory to evaluate conceptual understanding, emotional memory to assess affective responses, and narrative memory to reconstruct learning events as coherent developmental trajectories (Mace, J. H., Ingle, K. E., & Aaron, H. E. (2025); Grob et al., 2024).

4.3 A Theoretical Contribution: SRL as a Meta-Control System for Memory Access

This model conceptualizes SRL as a meta-regulatory system—a higher-order architecture that governs the selective activation and coordination of memory systems based on phase-specific demands, learner agency, and contextual cues. Emotional and narrative memory, in particular, function as cross-phase integrators, while procedural and perceptual memory dominate the performance phase. This framework offers a dynamic systems-level view of how musical memory is constructed, evaluated, and stabilized across time.

4.4 Implications for Instructional Design in Music Education

Music educators can use this model to align pedagogical strategies with phase-specific memory processes:

Forethought: Promote semantic-narrative rehearsal plans.

Performance: Support perceptual-procedural integration through multimodal and motor-focused tasks.

Reflection: Engage learners in structured self-review to activate semantic-emotional-narrative reprocessing.

This integrative model bridges cognitive psychology and educational psychology, offering actionable pathways to support autonomous and stable musical memory development.

5. Pedagogical Implications and Future Research Directions

The integration of cognitive memory systems with the self-regulated learning (SRL) framework provides a compelling theoretical and pedagogical foundation for transforming how musical memory is cultivated in both formal instruction and self-directed practice. Drawing on a decade of research in cognitive psychology, affective neuroscience, and educational metacognition, this model reframes music memorization not as the passive retention of notational information, but as the strategic orchestration of multiple memory systems across time-bound phases of learner regulation.

From a pedagogical standpoint, this approach calls for a fundamental shift in how musical instruction is designed and delivered. Rather than focusing exclusively on repetition and technical mastery, teachers are encouraged to act as regulatory facilitators, scaffolding students' phase-specific engagement with memory systems. In the forethought phase, instruction should explicitly activate semantic and narrative memory structures, guiding students to analyze formal elements, anticipate phrase structures, and construct affective narratives that will scaffold future recall (Gu et al., 2025; Thomsen et al., 2024). Students must be taught to plan not merely what to practice, but how to encode it conceptually and emotionally.

During the performance phase, instruction should focus on reinforcing procedural and perceptual memory pathways, optimizing the translation of intention into automatized execution. This includes designing practice that supports sensorimotor chunking, visual-auditory cue integration, and emotional expressivity under time constraints (Ye et al., 2024; Mylonas et al., 2024). Moreover, learners should be trained in in-situ metacognitive monitoring—the ability to detect, evaluate, and adjust their strategies in real time—a capacity closely tied to SRL effectiveness (McPherson et al., 2019).

In the self-reflection phase, teachers must foster deep post-performance analysis through semantic re-evaluation, narrative reconstruction, and emotional reappraisal. Tools such as reflective journaling, video-based feedback, and guided peer critique can help learners reprocess experiences not only cognitively but affectively, embedding new knowledge into long-term autobiographical and conceptual systems (Zhu, 2025; Mace et al., 2025). This phase is particularly critical in converting short-term procedural gains into stable, transferable musical memory.

Beyond pedagogical applications, the Memory × SRL model opens several fertile directions for future research. One urgent agenda is the longitudinal tracking of memory system dominance across learning trajectories—particularly how semantic, procedural, and narrative systems interact over weeks or months of rehearsal, and how this interaction is modulated by individual differences in SRL competence (Lund et al., 2025). Neurocognitive tools such as fMRI, EEG, and pupillometry could be used to capture real-time shifts in system activation during forethought, performance, and reflection cycles (Cabalo et al., 2024; Steel et al., 2024).

In addition, researchers should explore how emotionally salient and narratively framed interventions can serve as buffers against performance anxiety and memory decay. Studies in affective memory have shown that emotional congruence and autobiographical embedding increase memory resilience (Klune et al., 2021; Cooper et al., 2023), suggesting that expressive interpretation and personal connection may function as not only aesthetic goals but cognitive stabilizers.

There is also considerable potential for technological innovation in this space. Generative AI platforms and learning analytics dashboards could be employed to scaffold SRL phases, monitor memory engagement in real time, and provide phase-specific prompts for semantic or emotional recall (Zhu, 2025; Samsonovich et al., 2024). These systems may allow for adaptive instructional designs that tailor feedback and regulation strategies to the learner's moment-to-moment cognitive profile.

Finally, the cross-cultural and cross-genre applicability of this model warrants sustained inquiry. Future research could investigate how SRL–memory integration varies across Western classical, jazz improvisation, and non-Western oral traditions, or how cultural schemas influence narrative memory construction and emotional recall in performance contexts (Wani et al., 2025; Grob et al., 2024).

In sum, by treating SRL not merely as a behavioral strategy but as a meta-regulatory system for memory architecture, this model advances a multidimensional, dynamic, and context-sensitive account of musical memory development. It bridges theoretical paradigms in cognitive science and educational psychology while offering actionable pathways for pedagogical reform and empirical exploration. As music education moves toward greater personalization, emotional depth, and conceptual rigor, the integration of memory system theory with SRL phase modeling may become not only beneficial—but indispensable.

6. Conclusion

The formation of stable musical score memory is a complex process that defies simplistic explanations rooted in repetition or mechanistic skill acquisition. This review has proposed a multidimensional theoretical model that synthesizes two well-established psychological traditions: the multiple memory systems theory from cognitive neuroscience (Tulving, 1985; Squire, 2004) and the three-phase SRL framework from educational psychology (Zimmerman, 2000; Zimmerman & Moylan, 2009). By integrating semantic, emotional, perceptual, procedural, and narrative memory into the recursive SRL phases of forethought, performance, and reflection, this model reconceptualizes musical memorization as a dynamically regulated, system-coordinated learning process. Each memory system is not merely a storage unit, but a functional resource that interacts with regulatory strategies to support meaningful encoding, context-sensitive retrieval, and adaptive performance feedback. The Memory × SRL matrix thus serves as both a descriptive framework and a prescriptive map, guiding how memory systems are sequentially and hierarchically engaged under the orchestration of metacognitive and motivational control. It provides theoretical clarity on the cognitive architecture underlying expert musical memory and offers a scaffolding mechanism for fostering those same capacities in developing learners.

From an educational standpoint, this model urges a fundamental shift in pedagogical focus—from an emphasis on surface repetition and procedural fluency toward intentionally regulated, memory-informed learning design. Music educators must evolve from content transmitters into learning architects who structure rehearsal environments to activate the appropriate memory systems at each SRL phase. In the forethought phase, semantic and narrative priming through structural analysis and expressive visualization help encode meaning in advance of motor learning. During performance, procedural memory is strengthened through variable, goal-directed practice, while perceptual fluency is supported through sensory anchoring and feedback loops. In reflection, narrative and emotional memories are harnessed not only to process errors but to reconstruct artistic identity and reinforce long-term retention. By mapping instructional techniques directly onto the cognitive functions of each memory system, this model enables a highly personalized and phase-contingent pedagogy, where learners do not merely acquire musical material, but internalize it through strategic self-regulation. This supports the development of autonomous performers who can engage deeply with their repertoire, manage their learning trajectory, and retrieve expressive detail even under high-pressure conditions.

The theoretical model proposed also sets a forward-looking research agenda for cognitive musicology, educational neuroscience, and performance science. Empirical investigations should seek to trace temporal shifts in memory system engagement across learning cycles and learner types—potentially through longitudinal studies combining process tracing (e.g., SRL microanalysis, eye-tracking, introspective recall) with neuroimaging or EEG to examine functional connectivity. Moreover, further attention should be paid to emotional and narrative memory as mediators of performance resilience and expressive depth, especially under stress or in live performance environments (Klune et al., 2021; Cooper et al., 2023). Finally, the model invites exploration of how AI-enabled music education platforms might scaffold SRL and memory activation through adaptive feedback and generative modeling (Zhu, 2025; Samsonovich et al., 2024). As music education becomes increasingly globalized, multimodal, and digitally mediated, the intersection of SRL and memory systems provides a vital foundation for cultivating reflective, expressive, and self-directed musicianship across cultures and learning contexts. In this light, the memory a student builds is not simply a trace of past practice, but an active, evolving construct—authored through deliberate regulation and deeply embedded in the self.

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