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Construction of an AI-Empowered Closed-Loop Model for Dance Healing: Cognitive Support for Older Adults with Mild Cognitive Impairment

Zihan Li[1], Tuomeiciren Heyang[2,*], Wenjia Gu[3], Di Ma[4]

[1]*College of Arts, Shinawatra University, Pathum Thani 12160, Thailand*
[2]*Chengdu University, Chengdu, Sichuan 610106, China*
[3]*Shangrao Guangxin District Teaching Research Center, Shangrao, Jiangxi 334199, China*
[4]*Sichuan Southwest Vocational College of Civil Aviation, Chengdu, Sichuan 610499, China*
[*]*Corresponding author: 376452202@qq.com*

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Abstract: Older adults with mild cognitive impairment (MCI) are at a critical window for interventions addressing cognitive decline. Dance healing can engage cognitive processing through movement, rhythm, space, and interaction, yet its practical implementation still faces challenges, including insufficient individual adaptation, unclear links between cognitive support objectives and implementation phases, and inadequate use of process records and feedback. Grounded in embodied cognition theory, this paper combines literature analysis with theoretical deduction and incorporates suggestions from experts in relevant fields. It emphasizes the supporting role of AI technology throughout model operation and constructs an AI-empowered closed-loop model for dance healing consisting of five functional modules: Assessment Profiling, Regimen Generation, Implementation Embedding, Monitoring and Early Warning, and Feedback Iteration. Guided by the principle of practitioner leadership and AI assistance, the model puts cognitive support objectives into practice throughout the dance healing process and proposes corresponding implementation conditions and governance boundaries.

1. Introduction

Mild cognitive impairment (MCI) represents an intermediate state between normal aging and dementia, marking an important period for providing cognitive support [1,2]. As a practice mediated by movement, rhythm, and contextual interaction, dance healing can engage cognitive processing via motor learning, beat synchronization, spatial positioning, and interactive coordination [3,4]. Multiple studies suggest that dance-based activities may have positive effects on overall cognition, memory, attention, and balance in older adults with MCI [5,6,7].

However, operational challenges remain when dance healing is used to provide cognitive support for older adults with MCI. First, older adults with MCI differ in cognitive status and specific manifestations [8]. Dance healing implementation must also take into account physical tolerance, risk levels, and participation preferences; uniform activity content cannot fully address individualized support needs. Second, existing research on dance interventions focuses mainly on intervention effects or the content of specific programs, with insufficient explanation of how cognitive support objectives are translated into activity design and how activity design, implementation processes, and safety management are connected [6,7,9]. Third, existing research has not adequately recorded or used implementation processes or feedback from participants and practitioners, making it difficult to provide a stable basis for subsequent adjustments [9]. These issues indicate that existing research still lacks an operational framework connecting individual assessment, activity design, on-site implementation, safety management, and feedback-based adjustment.

With advances in digital health and intelligent sensing technologies, AI has demonstrated promising applications in supporting health service workflows, aggregating and integrating process data, recognizing and analyzing body postures, issuing risk alerts and optimizing feedback loops [10,11,12]. However, technological applications must be aligned with service workflows, usage contexts and accountability boundaries; technical capabilities cannot be equated with practical service capacity in isolation [13,14].

Against this background, this paper takes embodied cognition as its theoretical foundation and combines literature analysis with theoretical deduction. Based on a review of research on cognitive support for MCI, dance healing, digital health, and AI assistance, and considering the operational needs of dance healing activities before, during, and after implementation, it identifies five modules—Assessment Profiling, Regimen Generation, Implementation Embedding, Monitoring and Early Warning, and Feedback Iteration—and constructs an AI-empowered closed-loop model for dance healing. To enhance the model's practical adaptability and clarify the boundaries of its claims, the explanation of cognitive mechanisms, the configuration of key modules, and risk-control requirements were revised with reference to suggestions from experts in MCI and dance healing. These suggestions were used only for framework calibration and do not constitute independent empirical data.

The incremental contributions of this study are as follows: it integrates individual heterogeneity of older adults with MCI, cognitive support objectives, activity delivery, safety monitoring and feedback data into a unified closed-loop architecture. Under the collaborative framework of practitioner leadership and AI auxiliary support, dance healing delivery shifts from reliance on experiential judgment to adjustment informed by process documentation, feedback circulation and regimen updates. This paper thus provides a theoretical framework and analytical starting point for the structured implementation of dance healing and follow-up empirical research targeting cognitive support for older adults with MCI.

2. Concept Definition and Theoretical Foundation

2.1 Definition of Core Concepts

To avoid conceptual confusion, working definitions for five key terms are specified below:

Mild Cognitive Impairment (MCI): A state of mild cognitive deterioration situated between normal aging and dementia, characterized by perceptible cognitive decline while overall ability to perform activities of daily living remains intact [1,8].

Dance Healing: The term "dance healing" in this paper refers neither to pure dance skill training nor a practice predicated on formal clinical therapeutic relationships. It describes structured activities delivered by practitioners with relevant professional backgrounds or necessary training, leveraging physical movement, rhythm, spatial layout and interpersonal interaction as mediums. Such activities serve holistic physical-mental integration, cognitive support and emotional regulation [7,15,16]. Within the scope of this paper, its primary objective is cognitive support for older adults with MCI, with physical and emotional experiences generated during dance participation as secondary accompanying dimensions [15].

Embodied Cognition: Embodied cognition posits that cognition does not operate independently of the human body; instead, it develops and unfolds through physical movement, sensory experience and environmental interaction [3]. This theory is adopted herein to explain how dance healing delivers cognitive support for older adults with MCI via movement, rhythm, space and interaction, while providing theoretical underpinnings for the subsequent closed-loop model.

AI Empowerment: In this paper, "AI empowerment" refers to AI as technical support embedded throughout the dance healing closed-loop model, providing assistance with information organization, preliminary regimen drafting, process documentation, risk alerts, and feedback aggregation [10,13]. Its role is to assist practitioners with these tasks, while on-site leadership and final judgment remain with practitioners [13].

Closed-Loop Model: The "closed-loop model" refers to an interconnected operational structure of five modules (Assessment Profiling, Regimen Generation, Implementation Embedding, Monitoring and Early Warning, Feedback Iteration) driven by feedback circulation. Its core function is to leverage implementation outcomes as evidence for profile updates and regimen revisions, reducing overreliance on subjective experiential judgment for activity adjustments.

2.2 Theoretical Foundation

Cognitive impairment in MCI manifests across multiple domains including learning and memory, language, complex attention, executive function, social cognition and visuospatial capacity [8]. These domains establish the baseline for selecting cognitive support objectives. Embodied cognition further clarifies that cognitive processing is not merely an intracerebral activity decoupled from the body and environment; it is tightly intertwined with sensory perception, physical movement, bodily states and contextual interaction [3]. Within dance healing contexts, physical motions, musical rhythm, spatial shifts and peer interaction collectively constitute embodied experiences [4], which act as critical mediums to translate cognitive support objectives into practical activities.

Specifically, from an embodied cognition perspective, the mechanisms through which dance healing delivers cognitive support for older adults with MCI can be elaborated as follows: learning and repetitive practice of movement sequences serve as vehicles for supporting learning and memory; comprehension and expression linked to verbal cues, movement prompts, peer interaction and feedback sharing facilitate language function support; synchronized coordination of physical movements across rhythmic, spatial and interactive scenarios, alongside imitation, turn-taking, response and collaborative tasks, deliver targeted support for complex attention, executive function, social cognition and visuospatial capacity [3,4,8]. It should be noted that these cognitive domains do not correspond one-to-one with discrete tasks during dance healing; instead, they are activated concurrently and intertwined throughout activity execution.

Informed by embodied cognition theory, dance healing can translate cognitive support objectives into tangible practice via movement, rhythm, space and interaction, laying a foundation for subsequent Regimen Generation and on-site delivery. The closed-loop model further embeds this translational mechanism into a continuous workflow spanning five interconnected modules.

3. Construction of the AI-Empowered Dance Healing Closed-Loop Model

The AI-empowered dance healing closed-loop model comprises five functional modules: Assessment Profiling, Regimen Generation, Implementation Embedding, Monitoring and Early Warning, and Feedback Iteration, covering pre-implementation, in-implementation and post-implementation stages. Pre-implementation consists of Assessment Profiling and Regimen Generation to establish personalized foundations for activity delivery. In-implementation integrates Implementation Embedding and Monitoring and Early Warning to execute finalized regimens while maintaining requisite safety boundaries. Post-implementation relies on Feedback Iteration to aggregate process data, practitioner observational records and participant feedback, whose outcomes feed back into profile updates and subsequent regimen revisions, forming a practitioner-led closed-loop operational mechanism.

3.1 Assessment Profiling

Assessment Profiling organizes individual differences among participants based on existing clinical evaluation or screening data, encompassing initial file creation prior to activity commencement and dynamic updates following Feedback Iteration.

Profile content covers four dimensions: cognitive status, physical tolerance and risk, preferences and motivation, and digital technology acceptance. The cognitive status dimension draws on the six cognitive domains outlined above to identify participants' areas of impairment and individual differences [8]. The physical tolerance and risk dimension evaluates physical stamina, fatigue susceptibility, physical discomfort and balance hazards. The preferences and motivation dimension identifies receptivity toward musical styles, interactive formats and activity environments. The digital technology acceptance dimension gauges participants' willingness to engage with equipment, system prompts, process logging and human-machine interaction, providing reference for evaluating the adaptability of subsequent digital support tools [17,18].

Within this module, practitioners first review existing clinical assessment or screening materials, then conduct initial interviews and brief registrations targeting the four dimensions, supplemented by input from family members or caregivers when necessary. The AI system integrates all collected information to generate structured participant profiles, which practitioners cross-verify for key details. Validated profiles serve as personalized benchmarks for subsequent Regimen Generation, digital support selection and regimen revision. Practitioners bear no responsibility for formal MCI diagnosis within this workflow.

3.2 Regimen Generation

The term "regimen" in this paper does not refer to a medical prescription; it refers to a dance healing implementation plan developed on the basis of the assessment profile and tailored to the participant's condition. Regimen generation is based on a pre-established movement library. To align with cognitive support objectives and accommodate the physical activity characteristics and safety requirements of older adults, the movement library should be developed by screening, categorizing, and stratifying movement materials by difficulty, thereby providing the material basis for the AI system to generate a preliminary regimen.

During the AI preliminary regimen drafting phase, the system matches regimen content primarily using three profile dimensions: cognitive status, physical tolerance and risk, preferences and motivation. Based on cognitive status, the AI system matches movement difficulty tiers and proposes recommendations for movement element selection, choreographic sequencing, rhythmic pacing, spatial layout and group formation to align regimen content with targeted cognitive support objectives. Based on physical tolerance and risk, the AI system suggests rest points, pause conditions and early-termination conditions. Based on preferences and motivation, the AI system offers recommendations for group interaction organization and musical selection.

Practitioners then review and contextually revise the AI-generated preliminary regimen. First, they verify the alignment between the movements and cognitive support objectives and, where necessary, screen, reorganize, and modify the recommended content. Second, they review risk and safety boundaries, calibrate movement load, and determine alternative movements and safety contingency plans where necessary. Third, they adjust the music, interaction, and organizational arrangements in light of the actual implementation setting so that the regimen is suitable for on-site implementation.

The finalized regimen mainly includes an implementation script and a safety contingency plan. After completing the revisions, practitioners synchronize it with the AI system as a basis for subsequent implementation and monitoring. At the same time, an implementation feedback form is prepared on the basis of the finalized regimen for subsequent implementation records and Feedback Iteration (see Figure 1).

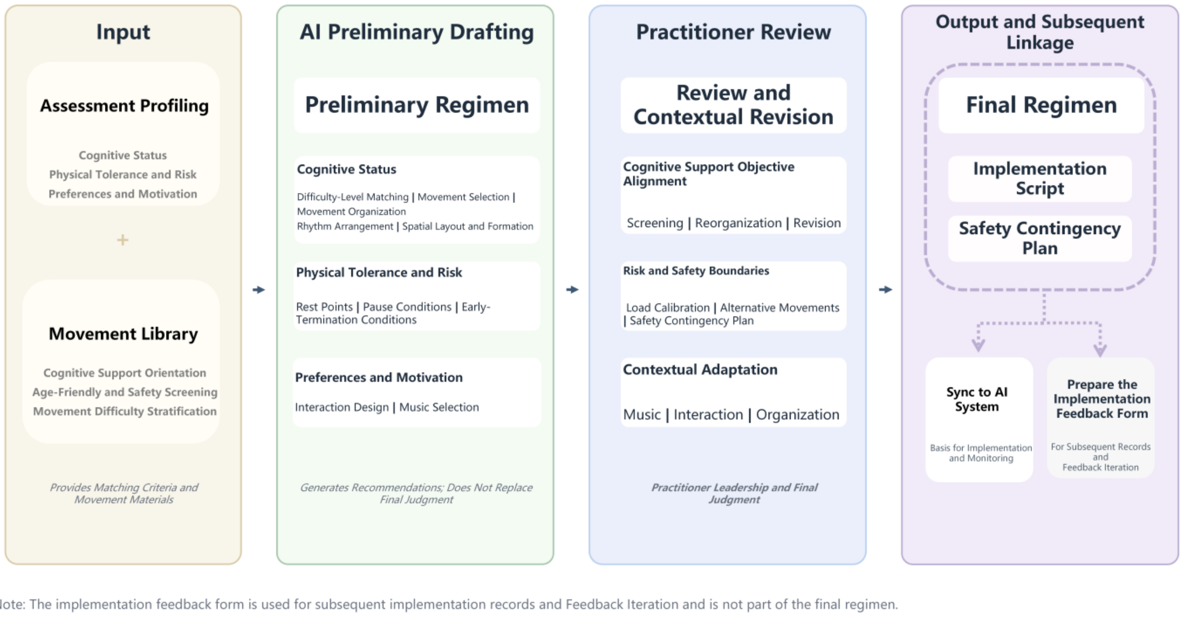

Figure 1: Flowchart of AI-Empowered Dance Healing Regimen Generation

Source: Original design by the authors

3.3 Implementation Embedding

Implementation Embedding aims to translate the cognitive support requirements in the final regimen into specific dance healing activities. Practitioners organize activities according to the implementation script while controlling the overall pace in light of the on-site process and participants' actual performance. During implementation, wearable devices, posture recognition, and other intelligent sensing methods may be used to collect relevant process data. With the final regimen as a reference, the AI system records and organizes implementation information to provide a basis for subsequent Feedback Iteration. This module focuses on implementing cognitive support arrangements and recording the implementation process; safety-related anomaly identification, alerts, and handling are managed by the Monitoring and Early Warning module.

3.4 Monitoring and Early Warning

Monitoring and Early Warning operates during activity implementation and is mainly used to identify safety anomalies and determine whether the rest points, pause conditions, or early-termination conditions specified in the regimen have been triggered. The AI system may use implementation process information and, where technical conditions permit, safety-related information obtained through wearable devices, posture recognition, and other methods to assist in identifying anomalies and issuing alerts [11,12]. Practitioners make judgments based on on-site observations, participants' immediate responses, and device or system alerts. Where necessary, they may extend rest periods, reduce movement difficulty, activate a safety contingency plan, pause the activity, or terminate it early.

3.5 Feedback Iteration

Feedback Iteration is the concluding module of the closed-loop model. It updates participant profiles on the basis of implementation outcomes and provides a reference for the next round of Regimen Generation. In this module, the AI system organizes implementation data and summarizes stable performance, performance fluctuations, and safety-related situations during regimen implementation. Practitioners make brief observational records of cognitive performance, physical tolerance, and risk-related responses, and collect brief participant feedback on activity intensity, preferences, participation experience, and experience with digital support. This information is compiled in the implementation feedback form and used to determine whether the next regimen should maintain the current arrangements, progress to a higher level, scale back, or substitute activities. It should be noted that the form is a procedural documentation tool and is not a standardized scale or an instrument for evaluating effectiveness. The feedback is then returned to Assessment Profiling to update information on cognitive status, physical tolerance and risk, preferences and motivation, and digital technology acceptance.

In summary, the five modules are not isolated from one another. Instead, through interconnection and functional coordination, they enable cognitive support objectives to be implemented throughout the dance healing process and adjusted on the basis of feedback. Feedback Iteration uses implementation outcomes to update profiles and adjust subsequent regimens, making it the key to closing the model loop (see Figure 2).

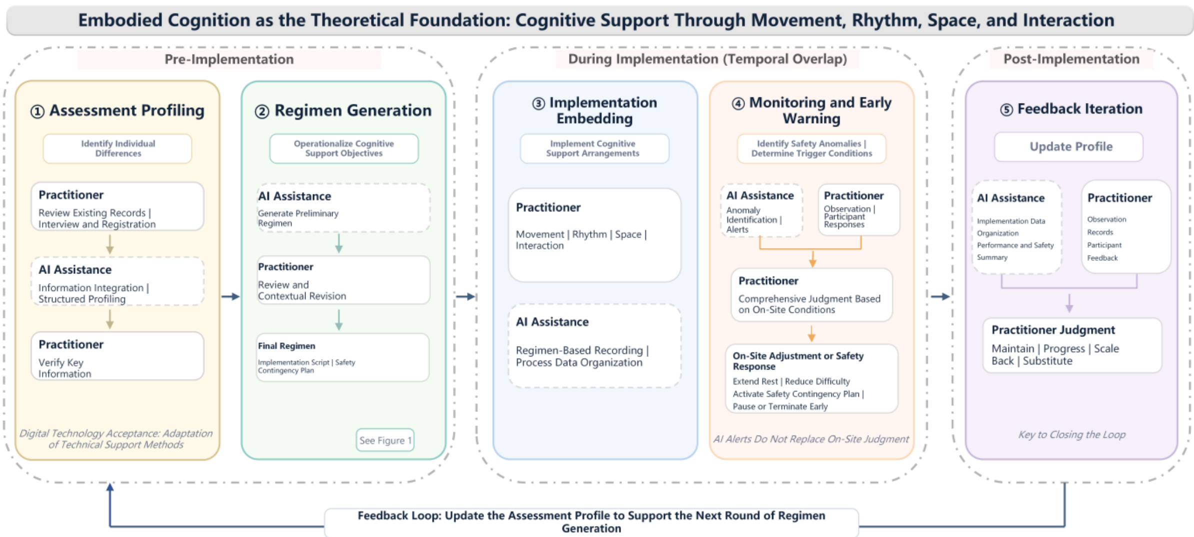

Figure 2: AI-Empowered Closed-Loop Model for Dance Healing

Source: Original design by the authors

4. Implementation Prerequisites and Governance Boundaries for Model Application

To deploy the AI-empowered dance healing closed-loop model within real-world delivery contexts, beyond clarifying its structural framework, clear personnel, procedural and technical prerequisites must be satisfied, alongside defined governance boundaries covering age-adapted design, data utilization and accountability allocation.

4.1 Implementation Prerequisites

First, practitioners must possess relevant professional training or foundational expertise, paired with core competencies in activity organization, risk identification and regimen interpretation. AI-driven information aggregation, process logging and feedback prompts can only deliver effective support for dance healing delivery when practitioners interpret and translate these outputs into on-site operational judgments [13,14].

Second, model operation should follow a simple process. Practitioners may use the implementation feedback form described above for process documentation, avoiding the addition of complex forms or duplicate materials beyond existing records. Digital support should serve practical needs rather than increase the burden on practitioners and participants [14].

Third, the model must accommodate heterogeneous delivery contexts. Complex high-cost equipment and sophisticated digital systems are not mandatory operational requirements; digital support modalities should be selected flexibly based on institutional resources, practitioner experience, participant group size and individual participant status [14].

4.2 Governance Boundaries

At the governance level, model application should address age-friendly support, data protection, and allocation of responsibility. Older adults' acceptance of digital technologies is influenced by usability, operational complexity, and available support [17,18]. Therefore, digital support used in the model should, as far as possible, maintain clear interaction and simple operation and provide necessary human assistance [18,19].

Data governance should follow the principles of informed consent, data minimization, and purpose limitation. Only information necessary for model operation, profile updating, regimen adjustment, and safety identification and alerts should be collected and retained. The scope of data use should be clearly defined throughout personal information processing, data circulation, and the use of results, in accordance with applicable ethical requirements and data governance standards [13,20].

Regarding accountability boundaries, AI systems provide support for information consolidation, process documentation, and risk alerts, and the resulting prompts serve only as references for practitioner judgment. Decisions on regimen adjustment, pausing activities, or activating a safety contingency plan should still be made by practitioners in light of on-site conditions and institutional safety requirements [13].

5. Conclusion and Future Research Outlook

Focusing on the cognitive support needs of older adults with MCI, this paper constructs an AI-empowered closed-loop model for dance healing based on embodied cognition theory and the structured characteristics of dance healing activities. The model comprises five core modules—Assessment Profiling, Regimen Generation, Implementation Embedding, Monitoring and Early Warning, and Feedback Iteration—and provides structured support for integrating cognitive support objectives into the implementation process before, during, and after implementation.

It should be noted that this study primarily develops a theoretical model and explains its operational mechanisms; it does not include the design of specific implementation plans, detailed movement combinations, intervention implementation, or verification of application effects. In addition, this paper defines the supporting role of AI in each module mainly at the functional and procedural levels and does not address specific system development, algorithm implementation, or device integration. The technical implementation of the model and its applicability across different settings may still be affected by personnel, institutional, technical, and governance conditions and require further testing and refinement in real-world implementation settings.

Future research may build on the existing model by using practitioner feedback, relevant expert consultation, and small-scale practical applications to examine the necessity, operability, and boundaries of applicability of the five modules. When conditions permit, quasi-experimental or randomized controlled studies may be conducted using cognitive assessment tools such as the Montreal Cognitive Assessment (MoCA) [21] to evaluate effects. Process evaluation using on-site observation, implementation feedback form records, and interview data [22] may further examine the model's cognitive support effects, activity participation, and feasibility of implementation.

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