

Development and preliminary evaluation of a dynamic cognitive training program for healthy older adults

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ABSTRACT

Background: Thailand is rapidly transitioning into a super-aged society, increasing the prevalence of age-related cognitive decline. Preserving cognitive function through evidence-based interventions is essential for active aging and independence.

Objectives: This study aimed to design, develop, and evaluate the content validity and feasibility of a multimodal dynamic cognitive training program through a systematic try-out process with healthy older adults.

Materials and methods: The study employed a three-phase research and development (R&D) framework: 1) program design based on neuroplasticity and the dynamic interactional model, 2) content validation by five experts, and 3) evaluating the program through a try-out with the target group (N=5, aged 64-73) over six weeks (12 sessions). Evaluation metrics included feasibility, acceptability, and preliminary cognitive outcomes using the Montreal Cognitive Assessment (MoCA), Digit Span Test, and subtests of the Dynamic Loewenstein Occupational Therapy Cognitive Assessment-Geriatric Version (DLOTCA-G).

Results: The cognitive training program was developed for improving attention, memory, visuospatial skills, and executive function. The cognitive training program, grounded in theories of information processing, neuroplasticity, cognitive retraining, and dynamic interaction, used a customized, multimodal framework. Over six weeks with biweekly 60-minute sessions, it combined cognitive exercises across three difficulty levels with physical activity. The program achieved an overall the Index of Item-Objective Congruence (IOC) of 0.98. During the Phase 3 try-out, participants demonstrated high engagement and 100% session attendance. Evaluation of cognitive outcomes showed positive trends in global cognition (100% of participants) and visuospatial function (100%).

Conclusion: The dynamic cognitive training program is valid and feasible. The try-out phase provided critical insights for program refinement, supporting its application in community-dwelling older adults to mitigate cognitive decline.

Introduction

The global demographic shift toward aging societies presents significant challenges, particularly regarding age-related cognitive decline.¹ Thailand has already transitioned into an aging society and is projected to become a super-aged society in the near future, with older adults constituting a rapidly increasing proportion of the population.² Age-related changes in brain structure and function may affect

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attention, memory, executive function, and decision-making, potentially progressing to cognitive impairment if not appropriately addressed.^{3,4}

Memory impairment is frequently identified as one of the earliest and most significant cognitive concerns among older adults. Because memory processes are fundamental to higher-order cognitive functioning, deficits in this domain may subsequently contribute to impairments in attention, visuospatial abilities, and executive functioning. Therefore, the development of integrated training programs targeting these interrelated cognitive domains is essential for mitigating progressive cognitive decline and supporting functional independence in later life. Maintaining cognitive function is also recognized as a central component of healthy aging frameworks.⁵

Accumulating evidence indicates that cognitive functioning in later life remains modifiable. The theory of neuroplasticity suggests that sustained cognitive engagement and enriched interaction with the environment can promote neural adaptation and cognitive optimization throughout the lifespan.^{6,7} Accordingly, cognitive training has been widely implemented as a preventive strategy to promote cognitive health among healthy older adults and those at risk of cognitive decline.⁸ The development of the present program was further informed by theoretical constructs of information processing, consistent with emerging neuroscientific evidence suggesting that cognitive task performance depends on the efficient transmission of information across distributed brain networks and optimal neural pathways.⁹ Recent evidence also indicates that interventions incorporating cognitively stimulating activities embedded within meaningful or everyday contexts may enhance engagement and support adaptive cognitive functioning in aging populations.¹⁰

Building on these perspectives, integrating physical movement with cognitive tasks has been shown to enhance cerebral blood flow and neural activation.¹¹ Additionally, game-based and multimodal interventions have demonstrated benefits in strengthening cognitive functioning and potentially reducing the risk of dementia.¹² Despite these promising findings, many existing cognitive training programs rely on standardized or fixed protocols that provide limited flexibility to accommodate individual differences in cognitive profiles, learning pace, and real-time performance changes. Such structured formats may restrict practical applicability, particularly for older adults whose cognitive abilities may fluctuate and require task adaptation, assistive strategies, or graded challenges to maintain optimal engagement.

Occupational therapists play a critical role in addressing age-related cognitive challenges by applying activity analysis and client-centered intervention principles to support cognitive functioning and occupational performance.^{13,14} Activity analysis enables therapists

to systematically examine task demands and environmental contexts, allowing activities to be selected and structured in ways that are meaningful and appropriate to individuals' roles, habits, values, and cognitive capacities.¹⁵ Within occupational therapy practice, cognitive-oriented interventions encompass a broad range of approaches, including training embedded within everyday activities, combined physical-cognitive interventions targeting functional outcomes, and structured activity-based programs designed to support memory, attention, and performance in daily living tasks.¹⁶ Although previous studies have reported promising outcomes from cognitive-oriented interventions, many publications provide limited descriptions of how task demands are progressively adjusted, how difficulty levels are tailored to individual performance, or how therapists actively mediate and adapt activities during intervention delivery. The absence of such detailed procedural information may reduce clinical reproducibility and hinder practical implementation, particularly in community-based settings where individualized adaptation and real-time clinical decision-making are essential components of occupational therapy practice.

Recent studies highlight increasing interest in the development of cognitive training interventions for older adults while also pointing to areas requiring further refinement. For example, Cruz *et al.* developed an online cognitive training program grounded in occupational therapy principles and reported positive user engagement and improvements in selected aspects of occupational performance and cognitive functioning among healthy older adults.¹⁷ In the Thai context, the TEAM-V program has been implemented to address multiple cognitive domains, including executive function, attention, memory, and visuospatial abilities, with follow-up studies reporting variable outcomes across domains and time points.^{18,19} Although some cognitive and functional benefits have been observed, the extent and consistency of effects across specific cognitive processes remain mixed, particularly for higher-order cognitive functions.

Despite this growing body of literature, several gaps remain. Many existing cognitive training programs rely on standardized task delivery and fixed session structures, with limited reporting on how task demands are dynamically adjusted in response to individual performance during intervention delivery.²⁰⁻²² Although multimodal elements are often incorporated, descriptions of real-time difficulty grading and therapist-mediated adaptation are frequently insufficient.^{20,21} Furthermore, few studies explicitly describe intervention frameworks grounded in occupational therapy-based dynamic assessment principles or provide systematic accounts of graded mediation processes, which are essential for clinical transparency, reproducibility, and translation into community-based practice.^{13,23}

In the present study, dynamic cognitive training is conceptualized as an occupational therapy-based intervention approach in which task selection, task demands, and therapist-mediated support are flexibly adjusted within each training session in response to individual performance and observed cognitive strategies. Consistent with occupational therapy practice principles, this approach emphasizes activity analysis, graded task demands, and clinical reasoning to support cognitive functioning within meaningful activity contexts. While the overall program structure, including the number, frequency, and duration of sessions, follows established cognitive training frameworks, adaptation occurs primarily at the activity level through real-time modification and graded mediation during task engagement.

Accordingly, this study aimed to develop and preliminarily evaluate a dynamic cognitive training program for healthy older adults using a structured yet flexible, therapist-mediated, and occupation-based framework. By integrating occupational therapy principles, dynamic assessment concepts, and culturally relevant activity design, the study provides methodological guidance for developing adaptable cognitive training programs suitable for community-dwelling older adults.

Materials and methods

Study design

This study employed a Research and Development (R&D) framework comprising three sequential phases: 1) program design and development, 2) expert content validation, and 3) program evaluation through a try-out

with the target group. This framework was selected to ensure the systematic development, theoretical grounding, and practical applicability of the dynamic cognitive training program. An overview of the study workflow is presented in Figure 1. Data collection was conducted between October 2024 and May 2025.

Phase 1: Program design and development

The dynamic cognitive training program for healthy older adults was developed as an individualized, therapist-mediated intervention grounded in occupational therapy principles, activity analysis, and neuroplasticity-informed cognitive training frameworks. Phase 1 represented the conceptual and theoretical design stage of the study, focusing on establishing the program structure, core components, and operational mechanisms rather than evaluating intervention outcomes.

As illustrated in Figure 1, the development process was guided by theoretical constructs of information processing, neuroplasticity, and dynamic interaction. These constructs were applied as guiding design principles to inform task selection, activity sequencing, and intervention delivery rather than as direct outcome measures. References to neuroplasticity within the flowchart denote the hypothesized mechanism underlying the program design (specifically, the role of repeated cognitive engagement, adaptive challenge, and enriched task interaction in supporting cognitive function) rather than empirically verified neural-level changes. Because the present study did not include neurophysiological or neuroimaging assessments, no direct conclusions regarding neural plasticity were drawn.

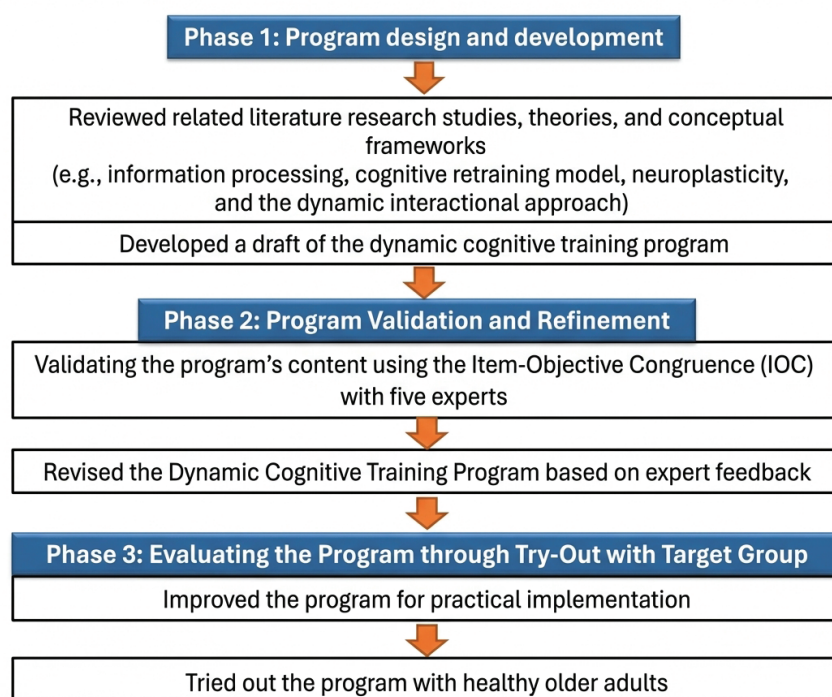


Figure 1. Research and Development (R&D) framework

Decisions regarding overall program duration, session length, and training frequency were informed by a structured synthesis of evidence from previous cognitive training and multimodal intervention studies involving older adults.^{7,8,13,16-19} This synthesis emphasized three methodological principles: 1) training dosage sufficiency, whereby repeated exposure across multiple sessions supports cognitive engagement and learning processes, 2) feasibility and adherence, prioritizing intervention schedules that are tolerable and sustainable for older adults, and 3) consistency with commonly reported cognitive training protocols in the literature.

Each training session followed a standardized yet flexible structure consisting of two main components. The first component involved a movement-based activity intended to promote arousal and readiness for cognitive engagement. The second component comprised two core cognitive training activities targeting multiple cognitive domains, including attention, memory, visuospatial ability, and executive function. In addition, brief home-based practice was assigned between sessions. These homework tasks were derived from the cognitive activities practiced during the training sessions and were intended to reinforce strategy use and task familiarity. Because the program was delivered twice weekly, participants were encouraged to perform home-based practice on non-training days to maintain continuous engagement throughout the seven-day training cycle. Homework performance was briefly reviewed at the beginning of the subsequent session to support continuity and learning consolidation.

The defining feature of the program's dynamic nature lay in the adaptive design of the cognitive training activities. All cognitive tasks were developed with adjustable difficulty levels, allowing real-time modification based on individual cognitive performance, strategy use, and responsiveness during training. When a participant was unable to complete a task accurately or independently, graded mediation strategies were applied using three predefined levels of support. This individualized adjustment aligns with personalization principles shown to improve engagement in health-related interventions.²⁴ Level 1 involved general mediation (e.g., repetition of instructions or neutral prompts). Level 2 consisted of targeted feedback, including performance-related cues or strategy suggestions. Level 3 involved task gradation, whereby task complexity, stimulus load, or rule demands were modified to maintain an optimal challenge level while preserving the therapeutic goal.

This graduated mediation framework aligns conceptually with mediation principles embedded within the Dynamic Loewenstein Occupational Therapy Cognitive Assessment-Geriatric Version (DLOTCA-G), which emphasizes examiner-mediated adaptation to reveal cognitive potential rather than static performance alone.²³ Decisions regarding mediation level and task

adjustment were guided by continuous observation of task accuracy, error patterns, response time, and the participant's ability to apply cognitive strategies.

All activities were additionally designed with explicit consideration of cultural relevance and contextual appropriateness for Thai older adults. Task content, visual materials, symbols, and examples were derived from familiar daily-life contexts to enhance ecological validity and meaningful engagement, consistent with occupational therapy principles emphasizing person-environment-occupation fit.

Phase 2: Program validation and refinement

The preliminary version of the dynamic cognitive training program was subjected to content validity assessment by a panel of five experts with recognized expertise in geriatric care. The panel comprised one geriatrician, one neurologist or family medicine specialist with a background in neuroscience, two occupational therapists with extensive experience in older adult rehabilitation, and one professor specializing in geriatric occupational therapy.

Content validity was systematically evaluated using the Index of Item-Objective Congruence (IOC). Experts independently assessed the program across six predefined domains: 1) alignment with the four targeted cognitive domains, 2) appropriateness of the session structure, 3) suitability of training frequency and interval, 4) logical sequencing of activities, 5) adequacy of mediation and task adaptation strategies, and 6) appropriateness of homework assignments.

Homework activities were included as a supplementary component of the intervention to encourage participants to maintain cognitive and physical engagement between training sessions. To ensure consistency in training exposure across participants, the homework activities were standardized according to the program protocol. Participants were assigned the same type of homework activity following each training session and were encouraged to complete the activity on days when they did not attend the scheduled training sessions. Each homework task required approximately 10-15 minutes and consisted of simplified versions of the cognitive or movement-based exercises introduced during the supervised sessions.

To monitor adherence, participants were asked to report completion of homework activities during the following training session, and the therapist briefly reviewed the tasks with participants when necessary. However, homework participation was intended as supportive practice rather than a mandatory component of the intervention. Therefore, the overall training intensity was primarily determined by the structured in-session activities delivered uniformly across participants. An $\text{IOC} \geq 0.5$ was considered acceptable.²⁵ Qualitative feedback provided by the experts was subsequently incorporated to refine and optimize the program prior to pilot implementation.

Phase 3: Evaluating the program through try-out with the target group.

This phase of the study focused on the development and preliminary evaluation of the intervention program. The program was a pilot-tested with five older adults to assess feasibility, clarity of procedures, and usability of the training activities prior to conducting a larger pilot study.

Participants

Participants included in this study were involved exclusively in Phase 3, which served as a preliminary evaluation aimed at determining the feasibility, acceptability, and practical implementation of the dynamic cognitive training program. In this study, “healthy older adults” were operationally defined as community-dwelling individuals aged 60-75 years who demonstrated intact global cognitive functioning and emotional status, and who were able to perform activities of daily living independently. Common age-related chronic conditions were not considered exclusion criteria, if participants did not have neurological or psychiatric disorders that could affect cognitive performance. Cognitive health was confirmed using the Thai version of the Montreal Cognitive Assessment (MoCA), with scores of 25 or higher indicating the absence of mild cognitive impairment. Emotional well-being was screened using the Thai Geriatric Depression Scale (TGDS-15), with scores below 5 indicating no clinically significant depressive symptoms. These criteria were applied to ensure that participants represented cognitively healthy older adults appropriate for preliminary feasibility testing of the dynamic cognitive training program. This phase was not intended to assess the efficacy of the intervention. Consequently, no formal sample size calculation based on statistical power was performed. Instead, a sample size of five participants was specifically designed as a formative usability testing and pre-pilot refinement process rather than a definitive quantitative feasibility study. This approach aligns with research and development (R&D) frameworks where small-scale try-outs are utilized to identify practical implementation challenges and refine intervention procedures prior to conducting larger scale trials.²⁶ To minimize the influence of confounding variables, participants were screened for stable medication and the absence of neurological or psychiatric conditions that could affect cognitive performance. Throughout the 6-week intervention, participants were formally instructed to maintain their regular daily routines, including their usual levels of physical exercise and social activities, and were requested to refrain from enrolling in any other structured cognitive or physical training programs.

Phase 3 was conducted to evaluate the feasibility of program implementation and to explore preliminary cognitive outcomes associated with the dynamic cognitive training program. A purposive sampling

approach was adopted to ensure that participants possessed the characteristics necessary for feasibility testing. Five community-dwelling, cognitively healthy older adults aged 60-75 years were recruited based on predefined eligibility criteria.

Instruments

To ensure a comprehensive and rigorous evaluation during the Phase 3 try-out, a complementary battery of cognitive assessments was employed:

MoCA

The MoCA was utilized as the gold-standard clinical screening instrument to verify inclusion criteria and provide a measure of global cognition. It ensured that all participants were cognitively healthy (excluding MCI) before the intervention. The Thai version of the MoCA was used as a standardized cognitive screening instrument to verify participant eligibility and to provide an index of global cognitive functioning. The MoCA was administered to ensure that all participants were cognitively healthy and did not meet criteria for mild cognitive impairment prior to participation in the intervention. The Thai MoCA has been culturally adapted and validated for use in Thai older adult populations and has demonstrated adequate psychometric properties for discriminating amnesic mild cognitive impairment from Alzheimer’s disease and cognitively healthy controls. Specifically, the instrument has shown good diagnostic accuracy, with reported areas under the receiver operating characteristic curve of 0.813 for amnesic mild cognitive impairment and 0.938 for Alzheimer’s disease, as well as acceptable sensitivity and specificity using cutoff scores appropriate for Thai clinical settings. In addition, evidence of strong test-retest and inter-rater reliability support the reliability and applicability of the Thai MoCA as a cognitive screening tool in this population.²⁷

TGDS-15:

The Thai version of the 15-item Geriatric Depression Scale (TGDS-15) was administered as a standardized screening instrument to identify depressive symptoms and to ensure participant eligibility for inclusion in the study. The TGDS-15 has been evaluated in Thai older adult populations and has demonstrated acceptable psychometric properties as a screening tool for major depressive disorder, including good sensitivity and specificity at a cutoff score of ≥ 5 .²⁸ These findings support its appropriateness for detecting clinically relevant depressive symptoms in geriatric settings in Thailand.

In Phase 3, depression screening was conducted prior to baseline cognitive assessment. Participants who scored ≥ 5 on the TGDS-15, indicating the presence of clinically significant

depressive symptoms, were excluded from the study. Only participants with TGDS-15 scores below the cutoff were invited to proceed to baseline cognitive assessments and participate in the intervention. The TGDS-15 was used exclusively for eligibility screening and was not included as an outcome measure in the analysis. This procedure was implemented to reduce potential confounding effects of depressive symptoms on cognitive performance and responsiveness to the training program.

DLOTCA-G

The DLOTCA-G was administered by trained occupational therapists following the original administration guidelines. The assessment is composed of multiple subtests designed to evaluate different aspects of cognitive functioning, and individual subtests may be administered selectively when a focused evaluation of cognitive processes is required. In this study, three specific subtests-Everyday Life Objects (memory), Visuo-construction (visuospatial function), and Thinking Operations (executive function) were used to obtain in-depth cognitive data. These subtests were selected because they include a mediation component that directly aligns with the dynamic intervention framework used in this study.^{23,29}

As the DLOTCA-G is a performance-based cognitive assessment involving therapist-guided tasks, the instructions were verbally explained in Thai to ensure participant comprehension, while the scoring procedures adhered to the standardized criteria described in the original manual. The subtests were interpreted according to the original scoring framework of instrument.²⁹

Although attention was one of the targeted cognitive domains in the intervention program, it was assessed separately using the Digit Span Test to allow a focused evaluation of attentional capacity and working memory, which are not independently isolated within the selected DLOTCA-G subtests.

Digit Span Test

The Digit Span Test was administered to assess attentional capacity and verbal working memory, addressing aspects of attention that are not independently captured by the selected DLOTCA-G subtests. The test consists of two components: Digit Span Forward, which primarily reflects attention span and immediate auditory attention, and Digit Span Backward, which additionally requires working memory and mental manipulation. In cognitively healthy adults, performance typically approximates an average span of 7±2 digits, reflecting normal attentional capacity. The Digit Span Test has shown

acceptable psychometric performance in older adult populations. Multiple studies, including de Paula et al.³⁰, report moderate to high reliability, with internal consistency coefficients typically ranging from 0.70 to 0.89 and test-retest reliability estimates of approximately 0.80 to 0.90 in older adults.

In the present study, both Digit Span Forward and Digit Span Backward were administered to evaluate attention and verbal working memory. The Digit Span Test was used as an outcome measure to describe individual-level changes in attentional performance following participation in the dynamic cognitive training program. All outcome measures were administered at two time points using the same assessment instruments: prior to the commencement of the intervention (pre-test) and immediately after completion of the 12-session dynamic cognitive training program (post-test). The Thai version of the MoCA, Digit Span Test (forward and backward), and selected subtests of the DLOTCA-G were used consistently at both pre-test and post-test to evaluate changes in global cognition, attention, memory, visuospatial ability, and executive function. The TGDS-15 was administered only at baseline as a screening tool to determine eligibility and was not included as an outcome measure.

Data analysis

Five older adults completed both baseline and post-intervention cognitive assessments across the targeted cognitive domains. At baseline, cognitive performance varied among participants. Given the exploratory and feasibility-oriented design of Phase 3 and the small sample size (N=5), data analysis was conducted descriptively to explore preliminary trends. Due to the small sample size, no definitive conclusions regarding feasibility in absolute quantitative terms were drawn; instead, the findings represent a preliminary assessment of the program's practical application.

Cognitive assessment scores were summarized using raw scores and individual-level changes between pre- and post-intervention assessments to illustrate patterns of change and variability across participants. This descriptive approach was adopted to explore preliminary trends and to support evaluation of program feasibility, rather than to test hypotheses or determine intervention efficacy. Accordingly, the findings from Phase 3 are interpreted cautiously and are intended to inform program refinement and the design of future studies with adequate sample sizes and statistical power.

Raw scores from the MoCA, Digit Span Test, and selected subtests of the DLOTCA-G were summarized and compared between pre- and post-intervention assessments. Although the intervention targeted four specific cognitive domains, the MoCA was included

to provide an overall indicator of global cognitive functioning and to contextualize domain-specific changes. Due to the standardized and proprietary nature of the assessment instruments, results are presented as raw scores with corresponding maximum possible scores to facilitate interpretation, rather than item-level reporting. The TGDS-15 was used exclusively as a screening instrument during participant recruitment to ensure eligibility for inclusion. TGDS-15 scores were not included in the outcome analysis and were not reported as part of the study results.

Results

Phase 1: Program design and development

Phase 1 resulted in the development of a structured dynamic cognitive training program for healthy older adults based on an integrated synthesis of occupational therapy theories, cognitive training principles, and evidence from prior studies.^{7,8,13,16-19} The finalized program framework reflects a multimodal and adaptive approach that combines physical movement, multi-domain cognitive stimulation, and therapist-mediated task adjustment.

Based on the synthesized evidence and design principles described in Phase 1, the program was structured as a six-week intervention consisting of 12 sessions, each lasting 60 minutes and delivered twice weekly. Each session included a preparatory movement-based activity, followed by two core cognitive training activities designed to engage multiple cognitive domains

simultaneously, and a structured home-based activity intended to reinforce learning.

The program incorporates a multimodal cognitive training framework that integrates physical movement with cognitive exercises to support neural activation and overall brain health.³¹⁻³³ Inspired by the “Brain Exercise” program described by Li *et al.*,³⁴ the intervention includes a preparatory phase consisting of movement-based warm-up activities, such as grid-based walking and hand coordination tasks,^{20,35} designed to promote spatial awareness and neurophysiological readiness prior to cognitively demanding activities. Each session engaged participants in at least two cognitive domains simultaneously, consistent with principles of dual-task and integrated cognitive stimulation.

The training program included a variety of task types, including game-based challenges, skill-oriented tasks, simulated real-life scenarios, and analytical reading exercises. These activities were selected based on evidence suggesting their potential to enhance neural connectivity and promote cognitive resilience in aging populations. All cognitive tasks were designed with adjustable difficulty levels and implemented using a predefined graded mediation framework to ensure individualized adaptation during training.

The finalized structure of the dynamic cognitive training program (including session composition, core components, targeted cognitive domains, and underlying theoretical principles) is summarized in Table 1.

Table 1. Description of a dynamic cognitive training program for healthy older adults.

Program	Activities	Description	Time (min)	Cognitive domain			
				A	W	VP	EF
1	Physical activity 1	Song-based gross motor activity enhancing attention, working memory	10	✓	✓		
	Cognitive activity 1-1	Which medicine, when? Remember pill details (color, amount, time) for each fictional character	25	✓	✓		
	Cognitive activity 1-2	Find the match mission: memorize a face and find the matching image among distractors	25	✓	✓		
2	Physical activity 2	Swing and sway: full-body rhythmic movement to upbeat music improving attention, memory, and visuo-construction	10	✓	✓		
	Cognitive activity 2-1	Whose number? Match phone numbers to characters after brief memorization	25	✓	✓		
	Cognitive activity 2-2	Block matching: recreate a block pattern based on a visual model	25	✓	✓	✓	

Table 1. Description of a dynamic cognitive training program for healthy older adults (continue).

Program	Activities	Description	Time (min)	Cognitive domain			
				A	W	VP	EF
3	Physical activity 3	Joy all day long: midline-crossing dance moves improving bilateral coordination and cognitive engagement.	10	✓	✓		
	Cognitive activity 3-1	Wise storyteller: sequence pictures and narrate a logical story.	25	✓	✓		✓
	Cognitive activity 3-2	Mystery compass: solve spatial puzzles using compass directions.	25	✓	✓	✓	
4	Physical activity 4	Rain dance: rhythmic movements crossing the midline to fun music.	10	✓	✓		
	Cognitive activity 4-1	Memory test: observe images and answer detailed questions.	25	✓	✓		
	Cognitive activity 4-2	Count it right: count objects in complex scenes accurately.	25	✓	✓		
5	Physical activity 5	Touch your body: follow verbal instructions to touch various body parts in rhythm.	10	✓	✓		
	Cognitive activity 5-1	Memory detective: spot and describe differences between similar people.	25	✓	✓		
	Cognitive activity 5-2	Hidden numbers: identify the missing number from a scrambled set.	25	✓	✓	✓	
6	Physical activity 6	Tour around: mimic vehicle movements (e.g., train, airplane) with rhythm.	10	✓	✓		
	Cognitive activity 6-1	Pack it up: plan and select items for a trip based on scenario conditions.	25	✓	✓	✓	✓
	Cognitive activity 6-2	Explorer's journey: use maps and clues to identify item locations.	25	✓	✓	✓	✓
7	Physical activity 7	Coordinated hand-body movements to upbeat songs.	10	✓	✓		
	Cognitive activity 7-1	Read and answer: read text and answer comprehension questions.	25	✓	✓	✓	✓
	Cognitive activity 7-2	Treasure hunt: solve clues using maps and directions to find treasure.	25	✓	✓	✓	✓

Table 1. Description of a dynamic cognitive training program for healthy older adults (continue).

Program	Activities	Description	Time (min)	Cognitive domain			
				A	W	VP	EF
8	Physical activity 8	9-Box Grid Walk: Navigate 3x3 Floor Grid with Verbal Cues	15	✓	✓	✓	✓
	Cognitive activity 8-1	Top chef: choose ingredients from a catalog to follow recipe rules	20	✓	✓	✓	✓
	Cognitive activity 8-2	Fair share: divide animals evenly under rule constraints	25	✓	✓	✓	✓
9	Physical activity 9	9-box grid walk with music 1: diagonal stepping to rhythmic instructions	15	✓	✓	✓	✓
	Cognitive activity 9-1	Where am i? Interpret maps to determine correct location	20	✓	✓	✓	✓
	Cognitive activity 9-2	Overlay puzzle: identify hidden objects in layered images	25	✓	✓	✓	✓
10	Physical activity 10	9-box grid walk with music 2: cross-body footwork to choreographed music	15	✓	✓	✓	✓
	Cognitive activity 10-1	Market budgeting: calculate purchases to stay within a spending limit	20	✓	✓	✓	✓
	Cognitive activity 10-2	Math riddle: solve layered math problems from story-based questions	25	✓	✓	✓	✓
11	Physical activity 11	9-box grid walk with music 3: dynamic foot patterns in triangle formation	15	✓	✓	✓	✓
	Cognitive activity 11-1	Global awareness: analyze global landmarks through visual cues	20	✓	✓	✓	✓
	Cognitive activity 11-2	Plan a trip: schedule and budget for domestic travel scenarios	20	✓	✓	✓	✓
12	Physical activity 12	9-box grid walk with music 4: diamond pattern steps to upbeat rhythm	25	✓	✓	✓	✓
	Cognitive activity 12-1	Garden planner: distribute garden plots and trees per specific conditions	15	✓	✓	✓	✓
	Cognitive activity 12-2	Pack before travel: select suitable items within weight limits and restrictions	20	✓	✓	✓	✓

Note: A: attention, W: working memory, VP: visuospatial function, EF: executive function.

The mediation procedures were implemented using a dynamic cueing hierarchy conceptually adapted from the DLOTCA-G. In this program, mediation was applied as a responsive and performance-based process in which therapist support was dynamically adjusted according to participants' observed performance during task engagement.

Across all cognitive activities, therapist mediation followed a three-level cueing hierarchy progressing from general prompts to increasingly specific guidance. This hierarchical structure enabled participants to attempt independent problem-solving while allowing therapists to provide graduated support when difficulties emerged. To preserve the intended cognitive demands of each activity, no more than three cues were typically provided within a single task before considering modification of task parameters. At Level 1 (general prompt), therapists provided neutral prompts or repeated task instructions to support comprehension and encourage participants to review available information. At Level 2 (guided prompt), therapists provided strategy-oriented cues directing attention toward relevant task features or suggesting alternative cognitive strategies. At Level 3 (specific prompt), therapists delivered more explicit cues by identifying inconsistencies or directing participants to re-examine task elements.

An example of this dynamic mediation process can be observed in Cognitive Activity 1-1, "Which medicine, when?" (Table 1). In this activity, participants were required to remember and match medication details (such as pill color, dosage, and administration time) for several fictional characters. The task required participants to encode and recall multiple pieces of information, thereby engaging attention and working memory processes.

During task performance, therapist mediation was applied dynamically based on participant responses. When a participant showed uncertainty or produced an incorrect response, the therapist initially provided a Level 1 prompt, encouraging independent review of the task information (e.g., "Try reviewing the pill information again and check the color, amount, and time carefully."). If the participant continued to have trouble, the therapist provided a Level 2 prompt, directing attention toward relevant task features or suggesting cognitive strategies (e.g., comparing medication schedules or verifying whether pill characteristics matched the correct character). If errors persisted, a Level 3 prompt was provided, in which the therapist offered more explicit cues by highlighting potential inconsistencies and encouraging the participant to re-examine specific task elements.

Through this graduated mediation process, therapist support was continuously adjusted according to participant performance, allowing individualized guidance while preserving the cognitive challenge of the activity and maintaining the core principles of the dynamic cognitive training framework.

Phase 2: Content validation of the training program

The objective of this phase was to assess the relevance, clarity, and appropriateness of the physical and cognitive training activities included in the intervention program. Content validation was performed using the IOC method to evaluate the extent to which each activity aligned with the intended training objectives, as judged by expert consensus. A panel of five experts was assembled for the validation process, including one geriatrician, one neurologist, two occupational therapists with experience in geriatric cognitive rehabilitation, and one academic specialist in occupational therapy and aging. Each expert independently evaluated the training activities across all 12 sessions of the program.

The IOC scores were calculated for each physical and cognitive training activity to evaluate content validity. Physical training activities demonstrated high levels of expert agreement, with individual IOC values ranging from 0.88 to 1.00 and an overall mean IOC score of 0.98, indicating strong alignment with the training objectives. Cognitive training activities showed uniformly high agreement, with all activities receiving IOC scores of 1.00 and an overall cognitive activities IOC score of 1.00.

The overall IOC score for the entire program was 0.98, reflecting excellent content validity. These findings indicate that both the physical and cognitive components of the training program are conceptually appropriate and well aligned with the intended objectives for healthy older adults. A summary of the IOC scores for each activity and program component is presented in Table 2. In addition to the quantitative IOC ratings, the experts provided qualitative feedback regarding the clarity, relevance, and feasibility of the program components. Attention was given to items with IOC values below 1.0, which were mainly related to the clarity of activity instructions and the description of certain program components. Based on these comments, several aspects of the program were refined. For example, experts noted that the instructions for some activities were not sufficiently clear for older adults, which contributed to slightly lower IOC ratings. Based on these comments, the wording of the instructions was revised and simplified to improve clarity and usability. Similarly, some experts indicated that the difficulty level of certain activities might vary depending on participants' cognitive abilities. These comments led to the refinement of activity descriptions and the inclusion of clearer guidelines for graded mediation and task adjustment within the program. These modifications improved the clarity, usability, and participant-friendliness of the program, ensuring that the final version was appropriate for implementation in the subsequent effectiveness study.

Table 2. Item-objective congruence (IOC) scores of physical and cognitive training activities.

Program	Physical activities	Score	Cognitive training activities	Score
1	Physical activities 1	1.00	Activity: 1-1 Activity: 1-2	0.88 1.00
2	Physical activities 2	1.00	Activity: 2-1 Activity: 2-2	0.88 1.00
3	Physical activities 3	1.00	Activity: 3-1 Activity: 3-2	0.92 1.00
4	Physical activities 4	1.00	Activity: 4-1 Activity: 4-2	0.96 1.00
5	Physical activities 5	1.00	Activity: 5-1 Activity: 5-2	0.96 0.96
6	Physical activities 6	1.00	Activity: 6-1 Activity: 6-2	0.96 0.96
7	Physical activities 7	1.00	Activity: 7-1 Activity: 7-2	0.96 0.96
8	Physical activities 8	1.00	Activity: 8-1 Activity: 8-2	0.96 0.96
9	Physical activities 9	1.00	Activity: 9-1 Activity: 9-2	0.96 0.96
10	Physical activities 10	1.00	Activity: 10-1 Activity: 10-2	0.96 0.96
11	Physical activities 11	1.00	Activity: 11-1 Activity: 11-2	0.96 0.96
12	Physical activities 12	1.00	Activity: 12-1 Activity: 12-2	0.96 0.96
Overall physical activities IOC score		1.00	Overall cognitive training activities IOC score	0.95

Overall program IOC score: 0.98

Note: IOC scores were calculated based on expert ratings of item relevance to program objectives. An IOC $\geq$ 0.50 indicates acceptable content validity.

Phase 3: Evaluating the program through try-out with the target group

Following the confirmation of content validity, the dynamic cognitive training program was pilot-tested with a group of five cognitively healthy older adults (aged 64-73 years) to assess its feasibility, acceptability, and preliminary usability in a community-based setting. The primary objectives of this phase were to determine whether the program could be delivered as intended, identify any barriers to participation or implementation, and gather initial feedback from participants regarding their experiences. Participants completed pre- and post-intervention cognitive assessments covering five domains: global cognition, attention, memory, visuospatial function, and executive function.

At baseline, cognitive performance varied among participants. To ensure personalized engagement, intervention activities were selected according to everyone's cognitive profile, age, and educational background. The program included three levels of task difficulty, allowing for tailored progression.

Adjustments to activity complexity and session pacing were made dynamically in response to participant feedback. These modifications were systematically documented using a real-time mediation system to ensure consistency and fidelity. Post-intervention results indicated improvements across all measured cognitive domains. Notably, all participants (100%) demonstrated increased MoCA scores, reflecting enhanced global cognitive functioning. Attention, as measured by the Digit Span test, improved in 60% of participants. Evaluation using the DLOTCA-G revealed gains in three domains: memory, visuospatial function, and executive function. Specifically, 80% of participants showed improvements in both memory and executive function, while visuospatial function improved in all participants (100%). These preliminary findings suggest that the individualized activity selection and responsive mediation strategies embedded within the program contributed meaningfully to the observed cognitive gains. Minor adjustments to session timing and pacing were made based on participant feedback

to optimize the flow between physical and cognitive components. These feasibility findings support the practical implementation of the program in larger-scale trials.

Five older adults (aged 64-73 years) completed both baseline and post-intervention assessments across five cognitive domains. At baseline, cognitive performance varied among participants. Following the intervention, improvements were observed across all assessed cognitive domains. All participants demonstrated increased MoCA scores (100%),

indicating enhanced global cognitive functioning. Improvements in attention, as measured by the Digit Span Test, were observed in three participants (60%). The DLOTCA-G subtests revealed improvements in memory and executive function in four participants (80%), while visuospatial function improved in all participants (100%). These findings suggest that individualized activity selection and real-time, responsive mediation may have contributed to the observed cognitive improvements. Detailed results are presented in Table 3.

Table 3. Demographic characteristics and individual pre- and post-intervention cognitive scores of participants in Phase 3.

Variables		Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Gender		Female	Female	Female	Male	Male
Age (year)		64	67	70	65	73
Education		Secondary M3 (lower secondary education)	Secondary M6 (upper secondary education)	Secondary M6 (upper secondary education)	Secondary M6 (upper secondary education)	Secondary M3 (lower secondary education)
Underlying diseases		DM, HT	DM	DM, DLP	HT	HT
Occupation		Retired farmer	Housewife	Community volunteer	Retired merchant	Retired merchant
MoCA Total score=30	Pre- Test	27	26	28	25	27
	Post- Test	28	27	29	27	28
Attention (Digit Span Test) Total score=16	Pre- Test	5	5	4	5	4
	Post- Test	6	5	5	6	5
Memory (DLOTCA-G) Total score=4	Pre- Test	3	2	3	4	3
	Post- Test	4	3	4	4	3
Visuospatial function (DLOTCA-G) Total score=5	Pre- Test	3	3	3	4	3
	Post- Test	4	4	4	5	4
Executive function (DLOTCA-G) Total score=5	Pre- Test	3	3	3	4	3
	Post- Test	4	4	4	4	4

Note: DM: diabetes mellitus, HT: hypertension, DLP: hyperlipidemia. Scores are presented as raw scores. Maximum possible scores for each instrument/subtest are provided to support interpretation.

Discussion

This study describes the systematic development, content validation, and preliminary feasibility evaluation of a multimodal dynamic cognitive training program designed for healthy older adults. Grounded in occupational therapy theory, neuroscience, and activity analysis, the program integrates physical activity and cognitive stimulation within a structured yet adaptable framework. The high Index of Item-Objective Congruence (IOC) scores obtained during content validation (overall IOC=0.98) indicate strong agreement among experts that the program components were relevant, clearly defined, and appropriate for the intended training objectives and target population.

Findings from the try-out phase further demonstrate that the program was feasible and well tolerated in a community-based setting. Participants showed high engagement throughout the six-week intervention and completed all training sessions. Although the primary purpose of this phase was to examine feasibility rather than intervention effectiveness, descriptive trends suggested improvements across several cognitive domains, including global cognition, attention, memory, visuospatial ability, and executive function. Importantly, IOC findings represent evidence of program content validity and should not be interpreted as evidence of intervention effectiveness.

Given the exploratory nature of the try-out phase and the small sample size, the observed changes should be interpreted as preliminary descriptive trends rather than definitive evidence of intervention efficacy. Although participants were instructed to maintain their usual daily routines and avoid participation in other structured cognitive training programs during the intervention period, unmeasured lifestyle factors cannot be entirely ruled out. Future studies using controlled designs and larger sample sizes will therefore be necessary to determine the effectiveness of the program.

All participants demonstrated increases in MoCA scores following the intervention, suggesting improvements in global cognitive functioning. Improvements in Digit Span performance were observed in three participants, indicating potential gains in attentional capacity and verbal working memory. Attention is widely recognized as a fundamental cognitive process supporting information processing and daily functional performance, and it is often among the earliest domains to decline during aging.

These findings align with previous studies reporting cognitive benefits from cognitively demanding training activities. For example, Shatil³⁶ reported improvements in attention and other cognitive domains following computerized cognitive training, both alone and in combination with physical activity. Although the assessment methods used in that study differed from the neuropsychological measures employed in the present research, the findings support the broader

premise that cognitively stimulating activities may contribute to improvements in attentional functioning in healthy older adults.

Improvements observed in memory, visuospatial function, and executive functioning using the DLOTCA-G subtests are also consistent with outcomes reported in other multimodal or adaptive cognitive training studies.^{23,29} For example, the Training Project Amsterdam Seniors and Stroke (TAPASS) trial demonstrated improvements in executive functioning and processing speed following task-switching training among healthy older adults.³⁷ Similarly, integrated cognitive-physical training paradigms, including Training Under Cognitive Kinematics (TUCK) and Useful Field of View (UFOV) interventions, have shown concurrent cognitive and motor benefits, highlighting the potential advantages of combining physical movement with cognitive challenge.^{38,39} The unique features of this study, such as individualized activity selection, difficulty-level adjustment, and real-time mediation, contributed to enhanced participant engagement, and improved intervention efficacy. Although the intervention was designed based on neuroplasticity-informed principles (such as graded challenge, task engagement, and therapist-mediated adaptation) neural plasticity was not directly measured. Therefore, references to neuroplasticity in this study describe the intended theoretical mechanism underlying the program design, not an empirically verified neural outcome. These tailored, responsive strategies echo findings from virtual-reality and adaptive programs that emphasize ecological validity and participant-centered design.^{40,41} These studies are cited here to provide conceptual context for combining cognitive challenge with movement-based tasks, rather than to imply direct comparability of outcomes. In contrast to fixed or predominantly computerized protocols, the present program emphasizes therapist-mediated adaptation and occupation-based activity selection informed by ongoing performance.²² Although the sample size was small, the study design and positive outcomes justify further investigation. Additionally, examining adherence, cost-effectiveness, and scalability across diverse settings will be essential for broader implementation.

Overall, the findings from this preliminary try-out suggest that the dynamic cognitive training program is feasible and acceptable for healthy older adults and may be associated with favorable descriptive trends across multiple cognitive domains. The individualized tailoring of activities, combined with real-time mediation and adaptive progression, may have contributed to participant engagement and observed changes in performance. All five participants demonstrated increased MoCA scores, indicating enhanced global cognitive performance. Improvements observed in the Digit Span Test among three participants indicate enhancements in attention, which is essential for daily

functioning and tends to be one of the first cognitive abilities to decline with age.⁴² Furthermore, while previous reviews have discussed the potential cost-effectiveness and scalability of computerized cognitive training programs,²¹ the present study did not evaluate economic outcomes. Cost-related considerations are therefore discussed only as broader contextual implications for future program development and implementation. LOTCA-G results further support these findings, with most participants showing improvements in memory and executive function, and all participants demonstrating enhanced visuospatial ability.

The individualized tailoring of activities, combined with real-time mediation and adaptive progression, may have contributed to participant engagement and observed changes in performance. These features are consistent with emerging evidence emphasizing the importance of personalized, ecologically relevant, and adaptive intervention designs in supporting cognitive health in aging populations.

Limitations

Despite the promising findings, several limitations of this study should be acknowledged. First, the small sample size (N=5) in the pilot phase limits the generalizability of the results and precluded the use of inferential statistical analyses. Although descriptive trends and qualitative feedback were positive, the absence of a control group restricts the ability to attribute observed cognitive changes solely to the intervention. Second, the short duration of follow-up prevents conclusions regarding the long-term sustainability of the observed cognitive changes. Third, while the intervention was personalized and flexibly delivered, it was implemented in a controlled, small-group setting. As a result, the feasibility of implementing the program in larger community or clinical contexts remains uncertain and may involve logistical, adherence, and resource-related challenges. Finally, the study focused exclusively on cognitively healthy older adults, which limits the applicability of the findings to other populations, such as individuals at risk for cognitive decline.

Future study

Future research should build on these preliminary findings by conducting larger-scale randomized controlled trials with adequate statistical power and appropriate control conditions to more rigorously evaluate intervention efficacy. Longitudinal study designs with extended follow-up periods are needed to assess the durability of cognitive changes and to determine whether booster sessions are necessary to maintain benefits. In addition, future studies should examine the scalability and real-world implementation of the program across diverse settings, including community centers, rehabilitation clinics, and home-based formats. Exploring the applicability of this

dynamic cognitive training program in populations at risk for cognitive decline, such as older adults with mild cognitive impairment (MCI), may also help clarify its potential preventive and translational value.

Conclusion

This study demonstrates the feasibility and acceptability of a dynamic, therapist-mediated cognitive training program for healthy older adults. The program's individualized and adaptive design, grounded in occupational therapy principles, supports its potential relevance for promoting cognitive engagement in community-dwelling older adults. Although conclusions regarding efficacy cannot be drawn from this preliminary try-out, the findings provide a foundation for future research employing larger samples and controlled designs to further examine effectiveness, scalability, and functional impact in real-world settings.

Ethical approval

Ethical approval for this study was obtained from the Ethics Committee of the Faculty of Associated Medical Sciences, Chiang Mai University (Approval No. AMSEC-67EX-034). All participants provided written informed consent prior to participation.

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Conflict of interest

The authors declare no conflicts of interest concerning the research, authorship, or publication of this article. All authors approved the final manuscript.

CRedit authorship contribution statement

Supawadee Putthinnoi: conceptualization and study design, writing: original draft, preparation and submission of the manuscript, corresponding author; **Warunya Sutthikampa:** data collection and analysis, development and design of training activities within the program; **Autchariya Punyakaew:** intellectual contribution to the development and design of training activities, data analysis; **Suchitporn Lersilp:** co-advisor, supervision of research methodology.

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