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Working memory program for improving language skills in older adults with mild neurocognitive disorders: A pilot study

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ABSTRACT

Background: Older adults with mild neurocognitive disorders (mild NCD) have a higher risk of major NCD. Cognitive deterioration can cause a deficit in working memory and language. Recent studies have shown some involvement overlapping the brain structure of working memory and language skills. Therefore, working memory intervention effectively enhances language skills in mild NCD. However, more research on this topic in Thailand is required.

Objectives: This study aimed to develop and implement a pilot study on a working memory program for improving language skills in older adults with mild NCD.

Materials and methods: This study was a developmental research design with two phases. Phase one involved the development and examination of the content validity of the working memory program for improving language skills by five experts. Phase two involved piloting the program with three older adults with mild NCD. The participants were asked to provide suggestions about the clarity of content and images, language usage, font size, the comprehensibility of instructions in each activity, and the quality of audio files used to complement the program activities through semi-structured interviews. Descriptive statistics were employed to analyze the collected data.

Results: The program comprised nine activities associated with the phonological loop, visual-spatial sketchpad, episodic buffer, and central executive tasks. The program's content validity was evaluated by five experts, resulting in a content validity index of 0.94, meeting the established criteria. Among the pilot users, three participants meeting the specified criteria indicated their ability to use and practice the program at home effectively. While most participants agreed that the images were clear and the font size was appropriate, there were concerns regarding the clarity of the training process steps and instructions. Additionally, some participants encountered challenges in accessing audio files through quick response (QR) codes.

Conclusion: In summary, the pilot study of the working memory program for improving language skills in older adults with mild NCD passed the content validity test and underwent revisions based on suggestions from the pilot users. Consequently, the program could enhance the language abilities of older adults with mild NCD. The next phase will investigate its effectiveness in improving language skills in older adults with mild NCD.

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Introduction

Mild neurocognitive disorders (mild NCD) is a term recently introduced to replace mild cognitive impairment (MCI) in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) published by the American Psychiatric Association (APA) in 2013.[1] Mild NCD is a progressive neurocognitive condition that can progress into major NCD. During the transitional phase, this condition may affect one or more cognitive functions, including complex attention, executive function, learning and memory, language, perceptual-motor skills, and social cognition.[2] Global studies conducted in 2012 and 2015 indicated a wide range of MCI prevalence rates, varying from 3% to 42% and 5% to 36.7%, respectively-prevalence of MCI in older individuals at 71.4%, which increased with age.[4]

In 2019, McCullough et al.[5] investigated language impairments in older adults with mild NCD. They found impairments in receptive language skills, such as comprehension from reading and listening, repetition, and language expression skills, including fluent speech, word recall, and concept definition. They also proposed a language skill rehabilitation approach involving working memory training to enhance neuroplasticity based on the underlying structure and functioning of working memory and overlapping language skills.[6] Additionally, Huntley and Howard's[7] study revealed that working memory deficits occur in the early stages of mild NCD, suggesting that working memory performance can indicate the progression of cognitive decline.

Working memory (WM) is the ability to hold and manipulate information while performing various daily tasks involving short-term storage and information processing. As a multi-component system, WM has a limited capacity to store information and allocate attention to different processes temporarily. It is closely linked to executive functioning, encompassing attention allocation, information selection, inhibition, and updating.[8] In 2000, Baddeley proposed a multi-component model of WM consisting of four components: the central executive, phonological loop, visual-spatial sketchpad, and episodic buffer.[9] The central executive is an attentional control system, consciously processing, manipulating, and storing information from other subsystems while regulating actions. The phonological loop temporarily stores and manipulates verbal information through articulatory rehearsal.

Similarly, the visual-spatial sketchpad operates but with different types of information and mechanisms, including visual, spatial, kinesthetic, and image decoding. Finally, the episodic buffer facilitates interaction among WM subsystems, their connection with long-term memory, and perception. Moreover, WM is also involved in retrieving information from long-term memory and language skills, especially comprehension from listening, reading, and verbal communication. For instance, during a conversation, individuals need to remember spoken words, organize the information, and retrieve data from long-term memory to process responses and engage in dialogue.[10] Deficiencies in working memory can lead to language and communication impairments in various aspects, such as listening, reading, language processing, understanding meaning, and complex syntax. This is because there are deficits in manipulating and processing incoming data.[11,12] Borella *et al*.'s study explored WM capacity in individuals aged 20 to 86 years and found that it declines with age.[13] Furthermore, they observed that lower WM capacity is associated with shorter, more straightforward phrases, less complex grammatical structures, and more error word selection and meaning.

As mentioned above, studies have applied the concept of WM to design activities for training healthy older adults and older adults with cognitive disorders. These activities, presented in formats like paper-pencil tasks and computer programs, were based on Baddeley's WM model. The applied activities involve listening and reading comprehension, verbal fluency, and engaging with images and texts. The study by Lee and Kim[14] investigated the effectiveness of WM training programs on language skills in older adults with mild to moderate cognitive impairment. They applied activities based on Baddeley's WM model and found that the WM training program had positively affected language skills. The participants demonstrated improved abilities in fluent speech, naming objects, defining words, and describing images compared to their performance before undergoing the training program. Likewise, Payne and Stine-Morrow[15] investigated the effectiveness of a WM training program called iTrain in enhancing language comprehension in older adults. This program involved computer-based training conducted at home, with 30-min sessions five days a week for three weeks (15 sessions). The findings revealed that the training's effectiveness extended to untrained language tasks, improving sentence comprehension and understanding of complex grammar.

There has been limited research on using WM training programs to promote language skills in Thailand's older adults with mild NCD. We designed a program based on Baddeley's WM model to address this research gap. It includes an exercise workbook and an answer key book, providing flexibility for older adults to self-train at home. The program aims to empower older adults with mild NCD to enhance their language skills and integrate them into their daily lives.

Materials and method

This study was divided into two phases: 1) To develop the program and examine content validity, and 2) to implement a pilot study of the program. Researchers developed and assessed it with three pilot users from May to October 2022 at a speech therapy clinic, Faculty of Associated Medical Sciences, Chiang Mai University.

Study design

This research was developmental research. The study aimed to develop a working memory program for improving language skills and investigate its feasibility for use with older adults with mild NCD.

Phase 1: Development of a working memory program for improving language skills

The researchers studied the theories and principles of speech training in older adults with mild NCD, knowledge about WM, and the development of WM programs to enhance language skills in older adults with mild NCD. This research was conducted by reviewing relevant literature and receiving guidance from experts specializing in cognitive rehabilitation in older adults with mild NCD. The activities are categorized according to the complexity of components based on Baddeley's WM model, activities based on Lee and Kim's study and Zimmermann *et al.*'s study.[14,16] The activities are divided into groups: Group 1, the phonological loop and visuospatial sketchpad, and Group 2, the central executive and episodic buffer. The program uses vocabulary from primary school word lists (grades 1-6) and adapted passages from a youth-oriented Thai encyclopedia for older adults with mild NCD. This selection ensured that the vocabulary consisted of familiar words used in daily life and was easily understandable. Accordingly, language and speech development in children at the primary education level occurs when they have an adequate vocabulary for communication and a grammatical structure similar to that of adults.[17] Hence, the designated content comprised uncomplicated vocabulary and everyday life scenarios. Moreover, the content of the activities was chosen based on Thai culture, language, and environment-activities and detail (Table 1).

Table 1. Description of activities on the working memory program on language skills[14,16]

Component of working memory	Activity	Description
Visuospatial sketchpad/ Phonological loop	Word list	Say and write the list of words presented.
	Picture list	Remember the presented picture and recall it by writing.
	Verbal fluency	Write the words of specific categories.
Episodic buffer/ Central executive	Missing item	Nine figures were shown in the 3*3 table. Next page, all figures remained in the same position, including the missing figure. Participants were asked to identify the missing figures.
	Day task/months task	At least three days or three months were presented in different sequences in a calendar on the page. Participants should order them mentally in calendar orders and write on the next page.
	Odd or even numbers of syllables in the word	Words were presented. Participants should mentally count the number of syllables in each and decide that word odd or even number
	Category span task	Present with a semantic category. Choose words that match the topic.
	Reading and recognition	Read a story and answer questions.
	Images and text	Read and remember text-related pictures, then fill in the text on the next page

We designed the program with paper-pencil activities for easy access, and participants could practice at their homes. The program consisted of two books:

1) Exercise Workbook: Part 1) provided an outline of the program. The training duration is six weeks, and each activity consists of six sets of exercises arranged in order of increasing difficulty, except for verbal fluency, which includes 18 exercise sets. This allows participants to recall vocabulary at the end of each training activity. Part 2) gave detailed instructions for each activity and training methods according to the program with sample activities. Part 3) Worksheets for participants to record activity performance.
2) Answer key book containing Part 4) the answer keys for the exercises.

Content validity

After The WM program for improving language skills had been developed, five experts (who had at least five years of specialization in cognitive-language rehabilitation) examined the WM program i.e., one geriatric psychiatrist, one lecturer in the field of language impairment in the older adults from The Faculty of Medicine Ramathibodi Hospital, Mahidol University. Additionally, one lecturer in occupational therapy for cognitive impairment from The Faculty of Associated Medical Sciences, Chiang Mai University, and two speech and language pathologists. The item-objective congruence (IOC) was IOC >0.5 and passed the criteria. The flowchart of Phase 1 can be seen in Figure 1.

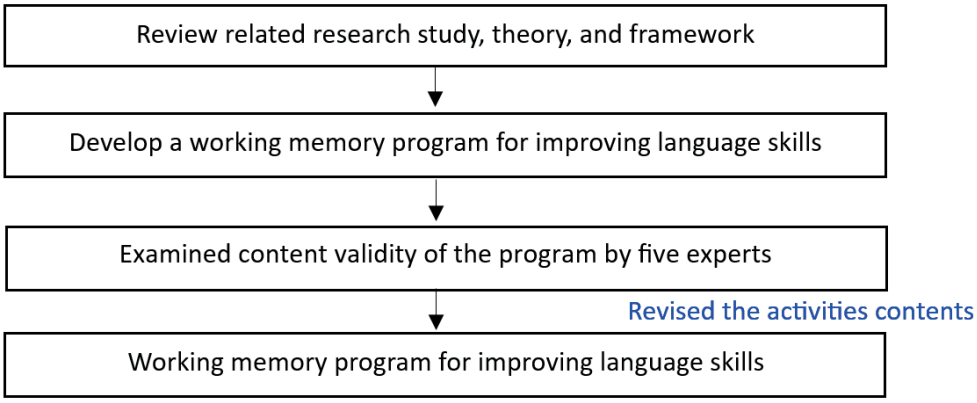

Figure 1. *Flow chart of the development process of working memory for improving language skills.*

Phase 2: trial of the working memory program for improving language skills with three pilot users

This phase aimed to investigate the usage feasibility of a working memory program for improving language skills in older adults with mild NCD. We revised the program contents following the experts' advice. Before the one-week pilot in October 2022 at a speech therapy clinic, Faculty of Associated Medical Sciences, Chiang Mai University, with three older adults with mild NCD. The inclusion criteria were (1) aged 60-79 years, (2) mild NCD diagnosis based on DSM-5 criteria and determined by a neurologist or geriatric psychiatrist, (3) no dementia, according to the Thai version of Mini-Cog,[18] 4) a cut-off score of 24 for mild NCD according to the Montreal Cognitive Assessment-Basic Thai version (MoCA-B-Thai),[19] 5) being independent when performing the Thai version of the Barthel Activities of Daily Living Index (Barthel ADL Index)[20], scale scores of ≥12, (6) not suffering from depression according to a cut-off score <6 on the Thai version of the 15-item Geriatric Depression Scale (TGDS-15),[21,22] (all of the instruments were screened by speech and language pathologists with more than five years of experience) and (7) spoke the Thai language and literate. The exclusion criteria were (1) a history of psychiatric disorders, (2) cerebrovascular accidents and brain injury, (3) vision and hearing problems that spectacles or hearing aids cannot fix, (4) substance or medication abuse, (5) used cognitive enhancers, and (6) participation in a cognitive training program during this study. Participants were selected based on the order in which they volunteered and met the inclusion criteria, including three older adults with mild NCD. The researcher described the details of the research project, demonstrated the program in various activities for one hour per individual, allowed them to practice independently, and obtained signed consent before the participants started the program at home for one week. Practicing by themselves in each activity for 25-30 minutes per session. The purpose was to assess the clarity of content and images, language usage, clarity of instructions in each activity, and the quality of audio files used in the program. We collected feedback and suggestions from three older adults with mild NCD through semi-structured interviews for the final minor revision of the WM program for improving language skills.

Instrumental for screening participant

1) The Thai version of Mini-Cog, a brief cognitive screening test, includes a three-item recall and a clock drawing test (CDT).[18] The three-item recall is scored up to three points, one for each correctly recalled word. The CDT requires drawing a circular clock displaying a specific time (11:10). Mini-Cog scores are categorized as (i) possible abnormal cognitive function (scores 0-2) and (ii) normal cognitive function (scores 3-5). This test showed good interrater reliability (K=0.80, p<0.001, 95% CI 0.50-1.00) and positive concurrent validity (r=0.47, p=0.007, 95% CI 0.37, 0.55) compared to the Mini-Mental State Examination Thai 2002.
2) The MoCA-B-Thai version was specifically developed to identify mild cognitive impairments in participants with limited educational attainment.[19] The scoring system includes assigning one point to individuals with ≤4 years of education and an additional point for low educational attainment. The optimal cut-off score is 24 out of 25. This test exhibited a high test-retest reliability of 0.91 (p<0.001) and had an internal consistency of 0.82.
3) The Thai version of the Barthel Activities of Daily Living Index (Barthel ADL Index) assesses the self-care and independence of geriatric individuals in a community setting.[20] The maximum score is 20. Participants with a score of ≥12 are considered independent. This assessment displayed Kappa inter-rater reliability coefficients and repeatability tests at 0.79 and 0.68, respectively.
4) The Thai version of the 15-item Geriatric Depression Scale (TGDS-15) serves as an effective screening tool for major depressive disorder in the Thai older adult population. The maximum score is 15.[21,22] Participants with a score of ≥6 (indicative of depression) were excluded from the study. This instrument demonstrated a sensitivity of 0.92 and a specificity of 0.87 in Geriatric Outpatients (cut-off score of ≥5) and a sensitivity of 100% and a specificity of 49% in the Thai Long-Term Care Home group (cut-off score of ≥8) when considering cognitively intact subjects.

Interview form for explicit problems that pilot users found during the practice of the WM program for improving language skills.

It is a semi-structured Interview form for gathering the opinions and problems found when using the WM program to improve language skills. The interview form focused on five topics: font size, size and clarity of images, accessibility and clarity of audio files, clarity of instructions, and overall usability and convenience. The opinion of the pilot users was recorded during the interviews.

Statistical analysis

The content validity and satisfaction of the pilot users were analyzed using descriptive statistics.

Results

Phase 1: Development of a working memory program for improving language skills.

The working memory (WM) program for improving language skills comprised nine activities, categorized according to the components of Baddeley's WM model. The activities were divided into two groups:

Group 1: Involving the phonological loop and the visuospatial sketchpad. The first activity was the 'word list' task, in which participants were asked to memorize words from audio files (e.g., mango and flower), then recall and write them in order in an exercise book. The second activity was the 'picture list' task, which required participants to remember presented pictures (e.g., lion and zebra) and then recall and write them in an exercise book. The third activity was verbal fluency, where participants wrote words related to specific categories (e.g., food, animal, sports).

Group 2: Involved the central executive and the episodic buffer. These activities included the 'missing item' task, where participants identify missing items on the second page (e.g., shirt, hat, shoes) after viewing the first page (e.g., shirt, hat, shoes, glove). The 'day task/months task' required participants to mentally arrange days or months in calendar order and write them on the next page. The 'odd or even numbers of syllables in the word' task involved mentally counting the syllables in each word and determining whether the count was odd or even. In the 'category span task,' participants selected words matching a given topic. The 'reading and recognition' activities involved reading a story (e.g., shopping in a market) and answering questions. In the last activity, 'Images and text,' participants read and remembered text-related pictures, then filled in the missing images and completed the text on the following page.

The researchers organized the program for each activity based on complexity levels within the WM model, progressing from easy to difficult. The activities gradually increase complexity by incorporating more words, phrases, texts, and images, corresponding to higher difficulty levels—this arrangement aimed to provide a challenging yet motivating experience for the participants.

According to the examined IOC, each item of the content validity test passed the criteria. (Table 2)

Table 2. Content validity of the working memory program for improving language skills.

Content validity			
Part	**Content**	**IOC**	**Conclusion**
1	Outline	0.90	Passed
2	Manual	0.94	Passed
3	Activity	0.95	Passed
4	Answer	0.98	Passed
total	All four parts	0.94	Passed

Phase 2: trial of the* working memory program for improving language skill*s with three pilot users.

When applied in the pilot group of older adults who met the inclusion criteria, consisting of three individuals, the demographic characteristics can be seen in Table 3. It was found that the pilot group could utilize the program for self-training at home. Overall, there was a consensus that clear images and font sizes were beneficial. However, there was some confusion regarding the training steps and instructions, and a few participants encountered difficulties opening the audio files from the QR codes. The researchers summarized feedback and revised the program based on suggestions. All suggestions are shown in Table 4

The researchers incorporated these adjustments according to the recommendations until the working memory program was complete. Furthermore, the researchers developed guidelines to explain the training processes, allowing the pilot group participants to understand and apply the training activities at home.

Table 3. General information of the pilot users.

N	Gender	Age	Years of education	Occupation	Instrumental for screening			
					The Thai version of Mini-Cog	Barthel ADL index	TGDS-15	The MoCA-B Thai version
1	Male	75	18	Retire	4	20	2	23
2	Female	77	6	Agriculturist	4	19	1	21
3	Female	71	12	Freelancer	5	20	1	22

Table 4. Satisfaction and suggestions from the pilot users.

Topic	Percentage (%)	Suggestion	Implementation
Font size	100	The font is large, clearly visible	-
Size and clarity of images	100	Appropriate image size. Clear images with beautiful colors that make one feel motivated to do the practice exercises. Older adults can recognize all images used in the training program and won't be confused when interpreting them.	-
Accessibility and clarity of audio files	67	The audio files have an adequately balanced volume, clear speech, and appropriate pauses between each word. However, the pilot users feel unfamiliar with accessing audio files via scanning QR codes.	Teach older adults to access audio files by scanning QR codes before proceeding with independent practice, and use the Line application to deliver audio files.
Clarity of instructions	67	The instructions are quite lengthy, causing confusion in some activities.	Revise the instructions for conciseness, and underline vocabulary words in the instructions. Allow older adults to try a sample activity before proceeding with independent practice.
Overall usability and convenience	100	At first, the experimental group was not familiar with using the practice workbook and the answer key. However, after trying the exercises, they found that practicing and checking their answers independently became much more convenient	-

Discussion

In the discussion section, we separate into two parts: The working memory program for improving language in older adults with mild NCD, and pilot users' satisfaction and suggestions.

Phase 1: The working memory program for improving language skills.

In content validity, experts recommended adjustments to the program's content. For example, in Part 1, the outline of the program's content, experts advised removing redundant content from the accompanying training manual, making the content more concise, and considering the difficulty level of certain activities. Additionally, since this program was designed for older adults to practice independently at home, it was essential to ensure a clear understanding of the training process, specifying the practice dates should be clear and providing guidance on self-assessment. It was suggested to make the content distinction between the exercise workbook and the answer key book to make sure everything is clear among older adults. In Part 2, the manual should use easily understandable categories for the exercises, with more examples and clear explanations for multi-step activities. In Part 3, Activity Worksheets, working memory activities involving listening, the experts suggested considerations regarding word selection. For example, words with similar sounds, the number of words, and the number of syllables can all affect memory in older adults, aligning with the "phonological similarity effect".[23] This concept is directly related to the auditory data storage unit. In other words, if letters or words with similar pronunciation are used, it can reduce the ability to retain information.

Additionally, word length is considered a significant

variable in hindering the process of word rehearsal. When multiple spoken words need to be memorized but cannot be repeated mentally, it can lead to rapid forgetting of those words. Furthermore, this program was designed to be accessible to older adults with mild NCD, without limitations based on educational levels. Therefore, the words in the program should be familiar words with a common name for better comprehension and recall. In activities related to images, experts have recommended using real images instead of cartoons. The images should be in color, appropriately sized, and proportioned realistically to allow the older adults to see them clearly and interpret the images accurately. This recommendation aligns with Myers' memory encoding process[24], which involves the initial process of receiving information from the environment, and transmitting data to visual and auditory receptors until it reaches the sensory areas in the cerebral cortex, resulting in sensory memory. Therefore, the stimuli must be clear and unambiguous. In Part 4 Answer keys, the researchers addressed discrepancies in Part 4 based on the experts' recommendations.

Moreover, for the WM program, the researchers used a single paradigm, emphasizing working memory training by utilizing various components within the working memory model. These components included a phonological loop, visual-spatial sketchpad, central executive, and episodic buffer. These activities were adapted from previous studies which adopted similar guidelines for training.[14,16] Alongside this, the study by von Bastian and Oberauer suggested that training focused on a single paradigm or specific skill might be more effective than multiple paradigms or diverse skills.[25] Furthermore, the program's activities were designed to gradually increase complexity, including expanding vocabulary, longer sentences, and complex tasks to enhance the WM capacity. This approach aligned with Lövden *et al*.'s idea that adaptive adjustments are necessary for survival when there is a 'mismatch' between living beings and environmental requirements.[26] This perspective is relevant to the studies conducted by Lee and Kim, Carretti *et al*., and Zimmermann *et al*.[14,27,16.] Their study adjusted the activity levels according to the participants' abilities and gradually increased the task difficulty. The findings indicated improvements in working memory capacity during usage and language skills.

Phase 2: pilot users' satisfaction and suggestions

In the pilot user phase, we demonstrated the feasibility of using the working memory program to improve language skills in older adults with mild NCD. Regarding this, most participants in the study expressed their positive satisfaction with the program. All of them (100%) agreed that the images were clear and the font size was appropriate. However, there were some concerns regarding the instructions' clarity. Additionally, some participants encountered challenges accessing audio files through QR codes (33%). We addressed this by teaching older adults how to access audio files by scanning QR codes before proceeding with independent practice. Furthermore, we utilized the Line application to deliver audio files and allowed older adults to try a sample activity before proceeding with independent practice. Based on their satisfaction and suggestions, as revealed by McGee, it is evident that older adults often experience impairments in sensory systems, including vision and hearing, and a decline in cognitive abilities.[28] Therefore, the development of the exercise workbook must consider usability factors. This includes providing clear explanations, relevant examples with accompanying images, using large font sizes, and incorporating real images, all enhancing visibility for older adults.

After revising the program based on the suggestions from pilot users, we developed the WM program for improving language skills. The program consists of two books: an Exercise Workbook, which contains an outline of the program, detailed instructions for each activity, training methods and protocol aligned with the program, as well as Worksheets for participants to record their activity performance, and an Answer Key book. The program comprises nine activities, each featuring different difficulty levels, ranging from easy to hard. These levels include an increasing number of words, phrases, texts, and images as the difficulty progresses. Inside the Exercise Workbook, you'll find clearly legible fonts and high-quality images with vibrant colors. The researcher has revised the instructions for conciseness and underlined vocabulary words for emphasis. Additionally, older adults are taught to access audio files by scanning QR codes before proceeding with independent practice. This program is designed for older adults with Mild NCD, who have decreased cognitive abilities compared to healthy older adults with the same educational level. Therefore, the researcher should be concerned about the content of the program, whether the words and images are appropriate for the Thai cultural context, making it easy for older adults with Mild NCD. The researcher should also consider the level of difficulty, accessibility, and comprehension limitations.

In addition, the pilot user group also provided feedback that home-based training allows for greater accessibility to training. This aligns with a previous study by Payne and Stine-Morrow[15] that investigated the effectiveness of a WM training program in enhancing language comprehension in older. The home-based training sessions lasted 30 minutes each and were conducted five times a week for three weeks, totaling 15 sessions. The study's results showed a statistically significant improvement in working memory capacity and language skills within the experimental group compared to the control group. Furthermore, the researchers suggested that home-based training could offer benefits such as increased convenience for older adults, reduced resource requirements, and greater flexibility in managing training schedules. These findings are consistent with a study conducted in Thailand by Pratoomtan *et al*., which explored the effects of home-based cognitive training on older adults with MCI.[29] In their study of 11 participants who underwent 18 training sessions over six weeks, it was discovered that older adults with MCI could engage in self-training activities and relied only partially on caregiver

assistance. Therefore, home-based training may be suitable for older adults with mild NCD.

Limitation

In this study, the limited duration of the second phase and the small sample size might impact program improvements. Nevertheless, the suggestion is valuable for future research investigating the program's effectiveness.

Conclusion

The working memory program for improving language skills consisted of nine activities, each containing different difficulty levels ranging from easy to hard. These levels included an increasing number of words, phrases, texts, and images according to higher difficulty levels. The program underwent content validity assessment by five experts and revisions based on suggestions from pilot users. Consequently, the program could enhance the language abilities of older adults with mild NCD. The next phase will investigate its effectiveness in improving language skills in older adults with mild NCD.

Ethical approval

This study was approved by the Research Ethics Committee of the Faculty of Associated Medical Sciences, Chiang Mai University (Approval ID: AMSEC-65EX-018) and the Research Ethics Committee of the Faculty of Medicine, Chiang Mai University Study code: None-2565-08999 Research ID:8999. All participants received all necessary information related to the research and informed written consent was gathered before enrolling.

Conflicts of interests

The authors declare that they have no conflict of interest.

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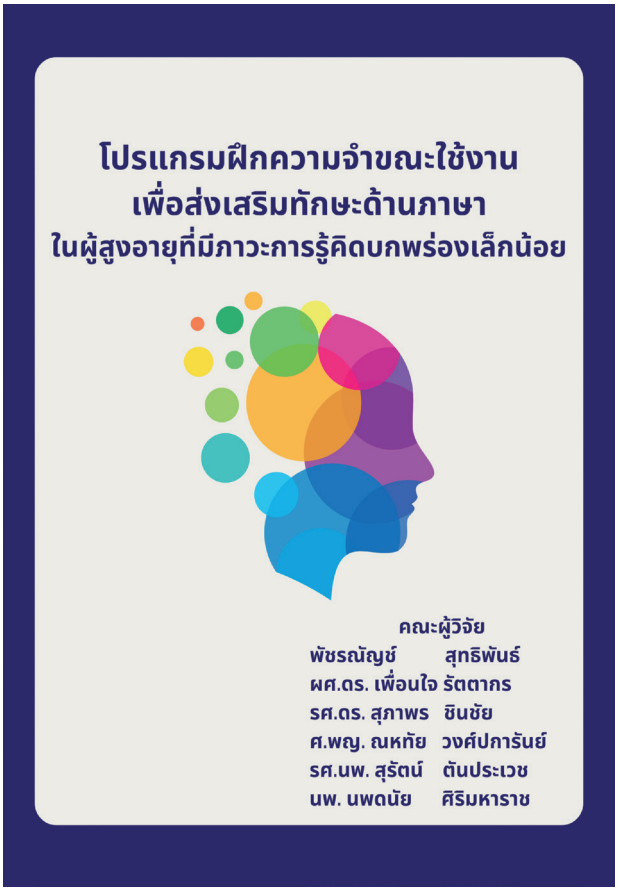
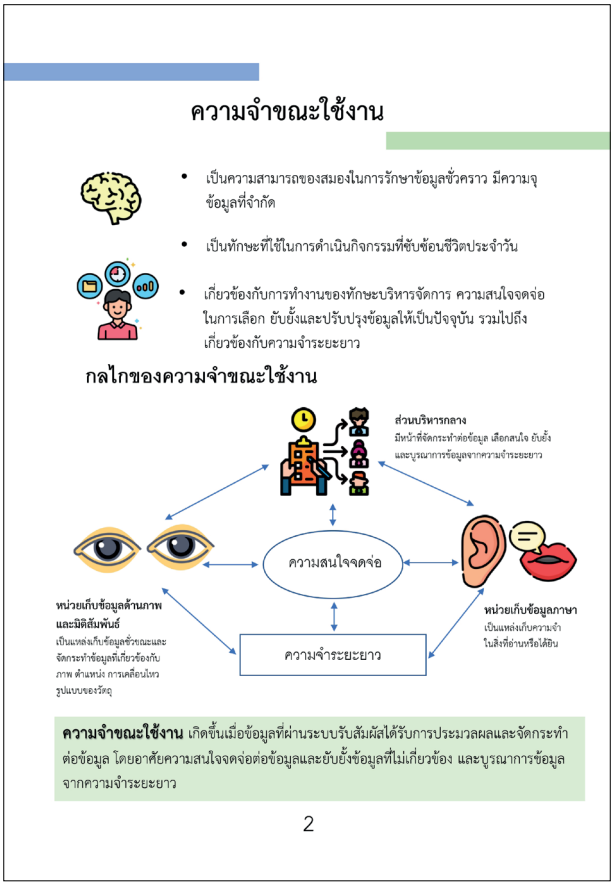
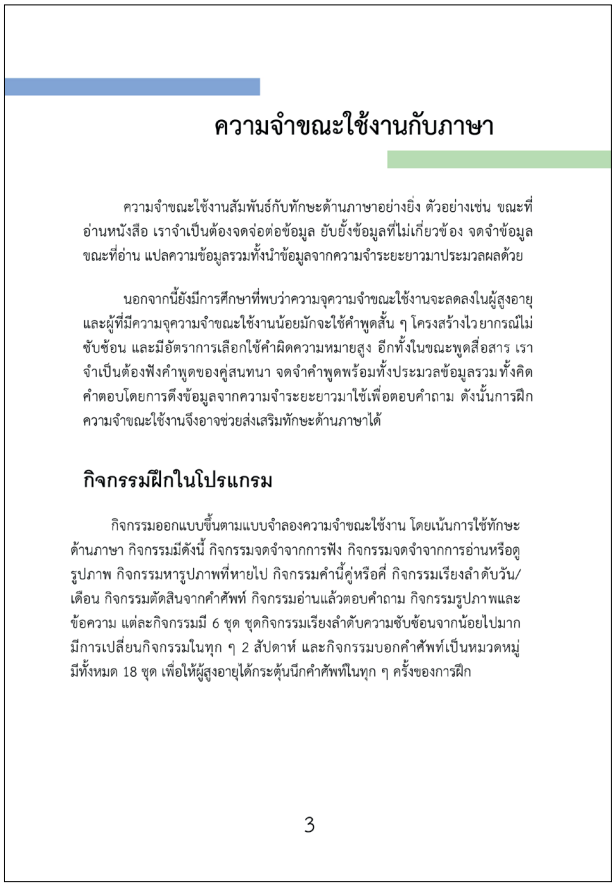
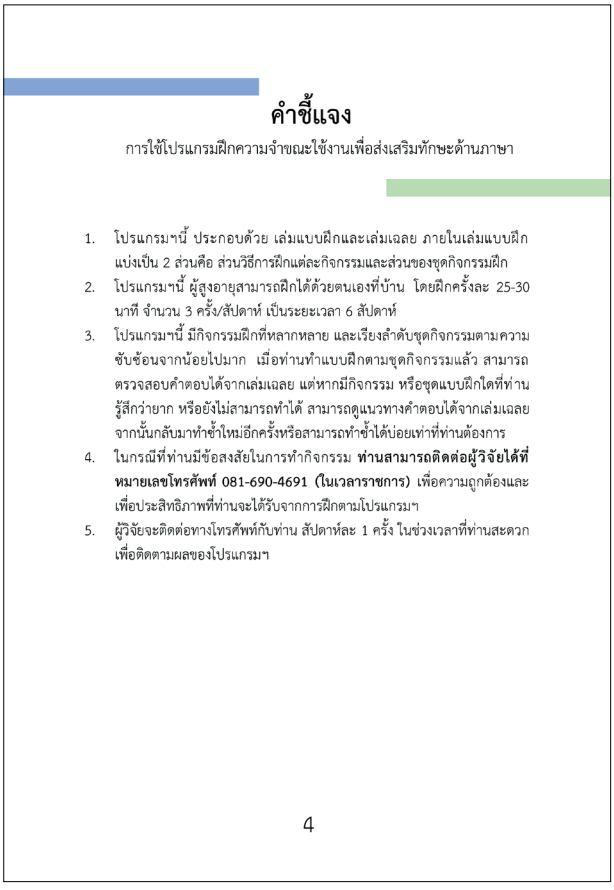
Appendix

Appendix 1. Example of a manual for using the working memory program for improving language skills.









Appendix 2. Example of activities in the working memory program for improving language skills.

วันที่ 1

กิจกรรมจดจำจากการฟัง **ชุดที่ 1**

คำชี้แจง สแกน QR code ฟังคำศัพท์จากไฟล์เสียง แล้วพูดทวนคำศัพท์ทั้งหมดหลังจากที่ได้ยิน จากนั้นเขียนคำศัพท์ที่ได้ยินลงในช่องว่างตามลำดับ

ข้อที่ 1 1. ..... 2. .....

ข้อที่ 2 1. ..... 2. .....

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วันที่ 1

กิจกรรมบอกคำศัพท์เป็นหมวดหมู่ **ชุดที่ 1**

คำชี้แจง เขียนคำศัพท์หมวด **ของใช้ในห้องครัว** ให้ได้มากที่สุด ภายในเวลา 5 นาที ลงในตาราง

คำศัพท์	คำศัพท์
1.	11.
2.	12.
3.	13.
4.	14.
5.	15.
6.	16.
7.	17.
8.	18.
9.	19.
10.	20.

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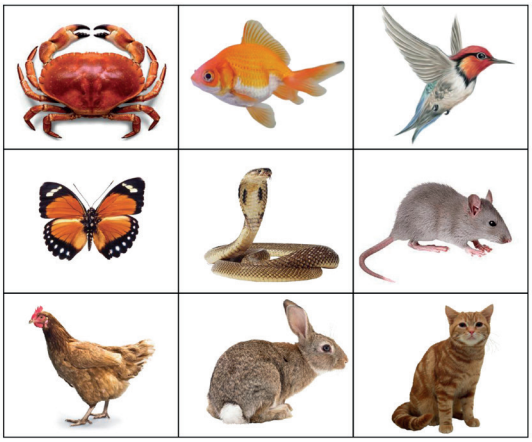
วันที่ 7

กิจกรรมหารูปภาพที่หายไป **ชุดที่ 1**

คำชี้แจง จดจำชื่อรูปภาพสัตว์ในตารางจนจำได้ทั้งหมด จากนั้นเปิดหน้าถัดไป เขียนชื่อรูปภาพสัตว์ที่หายไปในตำแหน่งเดียวกันลงในตาราง โดยไม่กลับมาเปิดหน้านี้ซ้ำอีก



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วันที่ 7

กิจกรรมคำนี้คู่หรือคี่ **ชุดที่ 1**

คำชี้แจง อ่านและตัดสินว่าคำศัพท์นั้น มีจำนวนพยางค์เป็นจำนวนคู่หรือคี่ โดยทำเครื่องหมาย ✓ ในช่องคำตอบที่เลือก

คำศัพท์	จำนวนพยางค์	
	จำนวนคี่	จำนวนคู่
1. ฉุกเฉิน		
2. เฉพาะกิจ		
3. ออกกำลังกาย		
4. ปกปักรักษา		
5. บุรุษไปรษณีย์		
6. อนุญาต		
7. ดวงอาทิตย์		
8. อาณาเขต		
9. ประชาธิปไตย		
10. สนุกสนาน		

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Appendix 3. Protocol of activities in the working memory program for improving language skills.

Week	Day 1	Day 2	Day 3
1	Word list	Word list	Word list
	Picture list	Picture list	Picture list
	Verbal fluency	Verbal fluency	Verbal fluency
2	**Day 4**	**Day 5**	**Day 6**
	Word list	Word list	Word list
	Picture list	Picture list	Picture list
	Verbal fluency	Verbal fluency	Verbal fluency
3	**Day 7**	**Day 8**	**Day 9**
	Missing item	Missing item	Missing item
	Day task/months task	Day task/months task	Day task/months task
	Odd or even numbers of syllables in the word	Odd or even numbers of syllables in the word	Odd or even numbers of syllables in the word
	Verbal fluency	Verbal fluency	Verbal fluency
4	**Day 10**	**Day 11**	**Day 12**
	Missing item	Missing item	Missing item
	Day task/months task	Day task/months task	Day task/months task
	Odd or even numbers of syllables in the word	Odd or even numbers of syllables in the word	Odd or even numbers of syllables in the word
	Verbal fluency	Verbal fluency	Verbal fluency
5	**Day 13**	**Day 14**	**Day 15**
	Category span task	Category span task	Category span task
	Reading and recognition	Reading and recognition	Reading and recognition
	Images and text	Images and text	Images and text
	Verbal fluency	Verbal fluency	Verbal fluency
6	**Day 16**	**Day 17**	**Day 18**
	Category span task	Category span task	Category span task
	Reading and recognition	Reading and recognition	Reading and recognition
	Images and text	Images and text	Images and text
	Verbal fluency	Verbal fluency	Verbal fluency