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International Journal of Speech-Language Pathology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/iasl20

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To cite this article: Jee Eun Sung, Sujin Choi, Geon Ha Kim & Jee Hyang Jeong (11 Dec 2023): Discourse-based verbal working memory training and transfer effects for individuals with an amnestic type of mild cognitive impairment, International Journal of Speech-Language Pathology, DOI: 10.1080/17549507.2023.2273771

To link to this article: https://doi.org/10.1080/17549507.2023.2273771

International Journal of Speech-Language Pathology, 2023; Early Online: 1–11

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Discourse-based verbal working memory training and transfer effects for individuals with an amnestic type of mild cognitive impairment

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Abstract

Purpose: The purpose of the study was to investigate the treatment efficacy of a discourse-based working memory (WM) protocol for individuals with the amnestic type of mild cognitive impairment (MCI).

Method: The current study employed a randomised, single-blind design. Fourteen individuals with MCI participated in the study ($n = 7$ treatment group and $n = 7$ control group). The treatment protocol consisted of 10 sessions two times per week, and treatment was individually administered only to the treatment group. A Wilcoxon signed-rank test was performed to verify pre-post comparisons within each group. Mann-Whitney nonparametric tests were conducted to confirm the differences between the treatment and control groups for the post-treatment scores.

Result: The treatment group demonstrated a significant increase in story-retelling outcomes for both the treated stories and untreated novel stories compared to the control group. Furthermore, the treatment group presented transfer effects for WM span measures and controlled word association tasks.

Conclusion: The results indicated that a discourse-based WM treatment protocol is efficacious for the amnestic type of mild cognitive impairment with the effects transferred to frontal lobe functions, as measured by WM tasks and semantic word fluency measures. Further studies are needed to track the trajectory of performance across sessions.

Keywords: *mild cognitive impairment; verbal working memory training; discourse-based treatment; treatment efficacy; transfer effects; generalisation effects*

Introduction

Mild cognitive impairment (MCI) has attained considerable attention as a transitional stage between normal ageing and dementia. Individuals with MCI demonstrate some decline in cognitive abilities but largely preserved activities of daily living (Petersen, 2004). Among several types of MCI, amnestic MCI (aMCI) is one of the most studied types, given that the conversion rate from the aMCI stage to Alzheimer's disease (AD) is reported to vary between 12% and 15% (e.g. Tabert et al., 2006). The construct of MCI has been critical to identifying individuals at an early stage of dementia. Early detection of cognitive and linguistic decline can contribute to providing therapeutic interventions for people with MCI.

Over the past few years, pharmacological treatments for MCI have been tested in randomised controlled trials. However, a systematic review by Raschetti and colleagues suggested that the pharmacological approach failed to show any delay in the progression to AD (Raschetti et al., 2007). More importantly, researchers reported the presence of side effects, thereby questioning the safety associated with pharmacological treatments for MCI (Jean, Bergeron, et al., 2010; Raschetti et al., 2007). Non-pharmacological strategies such as cognitive-linguistic training arise as potential treatment alternatives for MCI. Rodakowski et al. (2015) reviewed 32 randomised controlled trials investigating the effects of non-pharmacological interventions that included cognitive

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/17549507.2023.2273771.

ISSN 1754-9507 print/ISSN 1754-9515 online
Published by Taylor & Francis
DOI: 10.1080/17549507.2023.2273771

training, physical exercise, and psychotherapeutic interventions for individuals with MCI. The results demonstrated mixed findings depending on the types of non-pharmacological approaches. Cognitive training that tapped into memory- and attention-related domains indicated relatively greater promising impacts on cognitive changes in an early stage of cognitive decline, whereas training approaches that focused on physical exercise and remediation presented limited effect sizes. There is growing literature of evidence on memory-supportive cognitive training from the perspective of enhancing cognitive plasticity in elderly adults and individuals with MCI (c.f. Greenaway et al., 2008, 2013; Simon et al., 2012), suggesting that increasing cognitive activities based on memory and executive functions may compensate for the pathological changes associated with ageing.

Theoretical underpinnings for cognitive-linguistic training for elderly adults are often referred to as the cognitive reserve hypothesis (e.g. Stern, 2009). According to Stern (2009), the cognitive reserve model hypothesises that individual differences in cognitive capacity as a "mental fuel" may contribute to both managing available cognitive functions and preventing age-related decline in cognitive and linguistic processes. A meta-analysis suggested that people with higher cognitive reserve demonstrated a lower risk of progression to dementia than those with lower cognitive reserve (Valenzuela & Sachdev, 2006). Two studies suggest that cognitive reserve serves as a protective factor against cognitive decline and the onset of dementia in MCI. Allegri et al. (2010) reported that factors such as IQ, educational level, and job complexity were associated with cognitive reserve, accounting for 56% of the variability in the conversion from MCI to dementia. Nelson et al. (2021) demonstrated a strong association between higher levels of cognitive reserve and a decreased risk of MCI development. Furthermore, specific individual experiences, such as job position, educational level, and participation in socially and cognitively stimulating activities, not only facilitate the accumulation of neural resources over time but also establish the foundation of cognitive reserve. This cognitive reserve, fortified through brain-stimulating activities, mitigates cognitive decline caused by natural or pathological ageing (Cabeza et al., 2018).

Since cognitive reserve has accounted for individual differences in age-related decline in cognitive and linguistic processing, working memory capacity has received considerable attention. Working memory (WM) capacity is defined as the cognitive mechanisms associated with simultaneously maintaining and processing information over time (Just & Carpenter, 1992). Researchers have reported that WM capacity is susceptible to ageing (Daneman & Merikle, 1996; Hultsch et al., 1990) and have suggested memory training as a behavioural intervention approach.

Several review papers and meta-analyses have reported that cognitive training has beneficial effects, especially in memory for individuals with MCI (e.g. Belleville, 2008; Jean, Bergeron, et al., 2010; Simon et al., 2012; Zhao et al., 2022). However, cognitive-linguistic training programs vary widely across studies. As Simon et al. (2012) summarised in their review paper, some studies specifically focused on memory domains for individuals with MCI (e.g. Belleville, 2008; Jean, Simard, et al., 2010; Rapp et al., 2002; Vermeij et al., 2016), while other interventions involved multi-domains of facilitation including language, executive function, and visuospatial abilities (Law et al., 2022).

Among the many approaches, memory-based cognitive training has been the most frequently applied to test the hypothesis of cognitive training efficacy for MCI (e.g. Greenaway et al., 2008, 2013; Hernes et al., 2021, Lanzi & Bourgeois, 2020; Olchik et al., 2013, Vermeij et al., 2016). The cognitive training strategies have been approached from either a compensatory or restorative perspective. The compensatory-based approach aims to assist individuals with MCI by leveraging intact cognitive abilities or utilising alternative cognitive processes or external aids, such as memory notes, calendars, and phones, to compensate for their impaired functions. In contrast, the restorative-training approach involves retraining memory abilities to directly target and improve the impaired cognitive functions in MCI (Andrewes, 1996; Clare et al., 2013, Huckans et al., 2013). These strategies focus on stimulating and strengthening the specific cognitive processes that are affected. Researchers have reported that developing memory strategies has resulted in improvements in objective memory and cognitive functions, as well as decreased subjective memory complaints based on the restorative cognitive approach (e.g. Rapp et al., 2002; Yang et al., 2019). Greenway and colleagues examined the efficacy of the memory support system using a calendar/notebook system, and the results suggested that individuals with single-domain amnestic MCI demonstrated greater improvements in functional abilities and memory self-efficacy than those in the control group (Greenaway et al., 2013). Lanzi and Bourgeois (2020) reported evidence regarding the effects of using the external memory aid treatment for MCI. The authors suggested that individuals with mild memory impairments benefitted from using memory aids to enhance performance in their daily activities. However, any transfer effects of memory-based training have been controversial. Vermeij et al. (2016) reported that both healthy older adults and MCI patients demonstrated training gains on both trained and untrained items within the WM domains. However, transfer effects to other cognitive domains were rather limited. Furthermore, systematic reviews (Belleville, 2008; Jean, Bergeron, et al., 2010) have reported improvements after training mainly for memory domains. Meta-analyses from Papp et al. (2009) suggested that effect sizes were generally larger for outcome measures that are directly related to training, but its transfer effects to other cognitive domains were limited.

Other studies have suggested that the effects of WM training for the MCI group were transferred not only to the trained domain, but also to other non-trained cognitive functions. Weng et al. (2019) found that the effects of WM training in older adults with MCI were carried over to improvements in executive function and transferred to more comprehensive domains, such as abilities of daily living. Furthermore, these training and transfer effects were maintained for up to 3 months. Yang et al. (2019) administered virtual, interactive WM training programs to older adults with MCI. They reported this training program elicited improvement in WM tasks, reduced subjective memory complaints, and elicited transfer effects on general cognitive functions, as measured by the Mini-Mental State Examination (MMSE; Folstein et al., 1975). However, at the 3-month follow-up, only general cognitive functions were significantly maintained between the trained and untrained control groups. Carretti et al. (2013) reported that a WM training group with MCI performed better than a control group on verbal memory functions, as well as on non-trained cognitive domains such as visuospatial WM tasks, general fluid intelligence tasks (the Cattell test; Cattell & Cattell, 1960), and long-term memory tasks.

Previous studies that tested WM training effects encompassed various domains and levels of WM components in their treatment features, from non-linguistic to linguistic domains (e.g. Weng et al., 2019; Yang et al., 2019). Most studies did not explicitly delineate which components of WM their protocol directly taps into, given that most WM protocols include multiple features of mixed components of WM. However, due to the multifaceted features of WM training protocols from previous research, it is hard to disentangle which component of WM contributes to its efficacy.

Development of a discourse-based working memory training

The current study developed discourse-based WM training programs for individuals with MCI. The protocol specifically focused on enhancing verbal abilities to recall linguistic units at a discourse level. We incorporated the verbal and linguistic components of WM into the protocol, based on the assumption that verbal communicative improvement is more important than non-linguistic domains of WM in one's daily functions. Individuals with MCI have demonstrated difficulties in retrieving and manipulating linguistic units when novel information enters their limited memory buffer (Chen et al., 2019). One of the chief complaints of amnestic MCI is memory deficit, and this impairment is often reflected in word and discourse-level recall tasks from neuropsychological tests (Park et al., 2017). Based on previous findings of difficulties in retrieving information units (IUs) from a story, we developed a treatment program to improve the ability to retrieve units at a discourse level. We hypothesised that the underlying mechanisms involved in retrieving information from a story are associated with WM systems engaged in maintaining and processing information simultaneously (Just & Carpenter, 1992). Our treatment protocols incorporated WM components, including mnemonic strategies such as semantic-category facilitation and rearrangement of the keywords in a story so that participants could use keywords as an assistive device to retrieve the target story. Previous studies have developed various kinds of cognitive and linguistic training for individuals with MCI. However, multifaceted treatment programs encompass many components and, thus, make it difficult to find a theoretically-motivated treatment program that specifically targets linguistic levels. We applied WM theory to develop treatment programs, to include word-recall strategies by categorising words into each semantic category and rearranging linguistic information.

Aims of the study

The current study investigated the treatment efficacy of a discourse-based WM training program for aMCI using a randomised controlled design. We developed a discourse-based WM protocol using scripts by implementing the mnemonic strategies of WM, including semantic categorisation and association. The study specifically focused on examining the WM treatment on story-retelling abilities and its transfer effects on linguistic and cognitive domains. The specific aims of the study were (a) to examine whether there are significant differences in story-retelling abilities between the treatment group and control groups and (b) to investigate the transfer effects of the treatment on WM span measures and controlled word association measures. We predicted that the facilitation of WM components, such as storing and rearranging linguistic units, would elicit greater improvements in the treatment group than in their controls. We further hypothesised that transfer effects would be maximised to untreated domains through the facilitation of cognitive constructs, such as WM, that may serve cognitive reserves for the treatment group.

Method

Participants

The current study received approval from the Institutional Review Board of Ewha Womans University (No. 113-14), and written consent was obtained from all participants.

This study employed a parallel-group, randomised controlled trial design. Fourteen individuals with MCI were randomly assigned in a balanced enrolment ratio of 1:1 to either the treatment group or the control group. We recruited all participants from the Department of Neurology in a university-affiliated hospital and dementia support centre in Seoul, South Korea, and none of the participants dropped out during the study period. All participants were native, monolingual Korean speakers and they had corrected or normal visual acuity. All presented within the normal range on both the short version of the Geriatric Depression Scale (S-GDS; Jung et al., 1997) and the Korean-Instrumental Activities of Daily Living (K-IADL; Won et al., 2002).

All participants were diagnosed with MCI of the amnestic type by trained neurologists within 6 months prior to enrolment in the study and met the Petersen (2004) criteria: (a) subjective complaints of memory decline reported by the patient and/or confirmed by the caregiver, (b) objective memory impairments (<16th percentile of memory domain subtests from Seoul Neuropsychological Screening Battery-II (SNSB-II; Kang et al., 2012), (c) a normal range of general cognition as indicated by scores on the Korean version of the Mini-Mental State Examination (K-MMSE; Kang, 2006; ≥16th percentile with age- and education-adjusted norms), (d) preserved daily and social-life activities (based on K-IADL), (e) without dementia, and (f) without other medical, neurological, or psychiatric disease. Their Clinical Dementia Rating score (Hughes et al., 1982) was 0.5.

Baseline demographic data including results from neuropsychological tests are summarised in Table I. There were no significant differences between the treatment group and the control group for age (F [1, 12] = .165, p = .692), education (F [1, 12] = .208, p = .656), or the K-MMSE (F [1, 12] = .348, p = .566). None of the variables from the neuropsychological exams were significantly different between the groups.

Discourse-based working memory treatment protocol

The discourse-based WM treatment protocol was initially developed by Sung and colleagues (2016), and Choi et al. (2021) included and used the protocol in some of the case report treatment programs for the patient with moyamoya disease. This treatment protocol used stories about five familiar themes occurring in daily life. The novel script topics for treated stories used in the protocol (Choi et al., 2021) include going to the market, getting medical treatment, going on a picnic at the zoo, meeting friends, and going on a trip. To enhance the WM ability to semantically classify keywords, each story contained keywords with high semantic familiarity for most Korean older adults that belonged to four to five semantic categories (e.g. fruits, vegetables, transportation, body parts, food).

Each of the five scripts for treated stories was composed of nine complex sentences, and all of the sentences were determined with IUs containing content words and function words (e.g. case marker). The mean of the IUs for the five stories was 135.8 (SD = 4.32), with a range of 130–141 IUs. The number of IUs within each story was balanced and evenly distributed. The classification criteria for IUs were validated by the researchers in this study. Specific treatment steps from the protocol are delineated below, and details about the treatment administration are provided in Figure 1.

Step 1. Story retelling: Participants listened to the whole story and performed the story-retelling task in as much detail as possible. Regardless of the story-retelling performance, they then answered the eight comprehension questions about the IUs in the story. The questions were open ended asking for the main information about time, place, person, and other details related to the events in the story. Taking the story Going on a Picnic as an example, the participants listened to the story and answered questions, such as “what grade is your granddaughter in this year?” (related to the person), “what time did the grandfather book the train at

Table I. Demographic information and descriptive data from neuropsychological tests.

Characteristics	Treatment group mean (*SD*)	Control group mean (*SD*)	Normative data mean score (*SD*)
Age (years)	71.428 (4.913)	73.000 (5.597)	–
Sex (male:female)	5:2	6:1	–
Education (years)	6.143 (6.884)	4.786 (3.806)	–
K-MMSE[a] (/30)	23.000 (3.915)	24.286 (4.231)	26.72 (2.23)
SVLT[b] immediate (/36)	17.714 (8.400)	14.286 (6.019)	16.10 (4.33)
SVLT delayed (/12)	4.429 (4.197)	3.286 (3.093)	4.49 (2.22)
SVLT recognition, true (/12)	9.857 (2.193)	8.571 (2.572)	9.55 (1.83)
SVLT recognition, false (/12)	5.000 (4.830)	5.429 (3.690)	1.86 (1.49)
RCFT[c] copy (/36)	30.714 (7.521)	28.357 (6.896)	29.86 (5.04)
RCFT immediate (/36)	12.214 (6.303)	11.000 (9.903)	11.98 (5.8)
RCFT delayed (/36)	12.071 (7.435)	9.429 (7.322)	11.81 (5.63)
KCWST[d] colour (/112)	68.429 (16.621)	55.000 (33.862)	66.58 (19.47)
KCWST word (/112)	69.714 (43.234)	73.000 (30.364)	72.01 (19.47)

Note. Standard deviations are presented in parentheses.
[a]K-MMSE = Korean-Mini Mental State Examination (Kang, 2006).
[b]SVLT = Seoul Verbal Learning Test from Seoul Neuropsychological Screening Battery-II (Kang et al., 2012).
[c]RCFT = Rey Complex Figure Test from Seoul Neuropsychological Screening Battery-II (Kang et al., 2012).
[d]KCWST = Korean version of Colour Word Stroop Test from Seoul Neuropsychological Screening Battery-II (Kang et al., 2012).

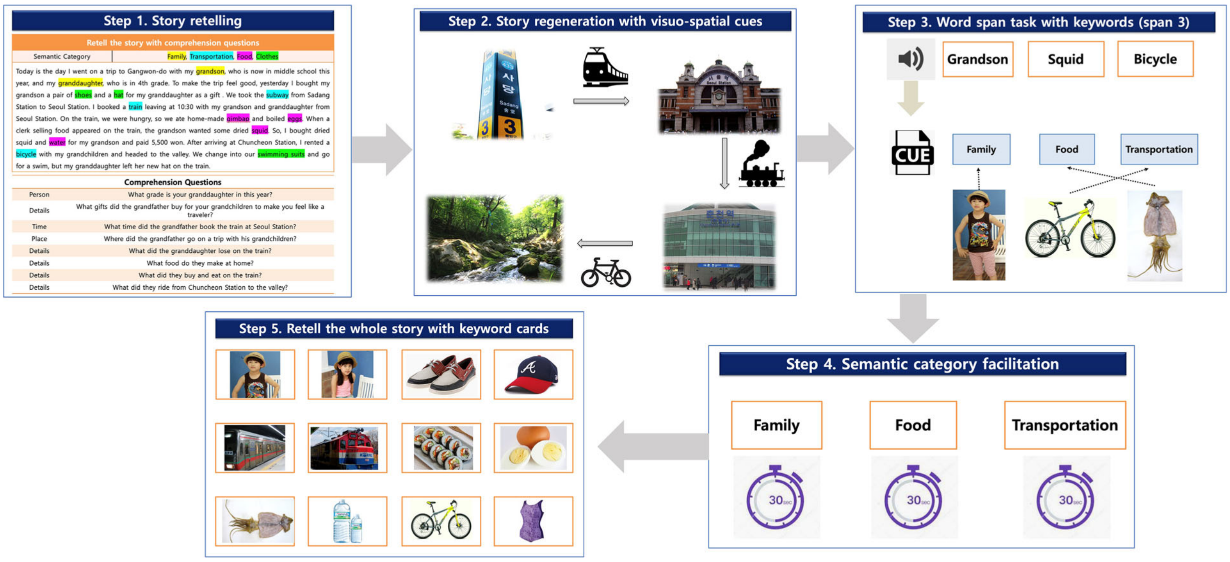


Figure 1. An example of discourse-based working memory treatment protocol (going on a picnic).

Seoul Station?" (related to the time), "where did the grandfather go on a trip with his grandchildren?" (related to the place), and "what did they ride from Chuncheon Station to the valley?" (related to the details).

Step 2. Story regeneration with visuospatial cues: The speech-language pathologist (SLP) randomly presented place and transportation cards, and asked participants to rearrange these picture cards in the order heard in the story. Participants were asked to retell the story while arranging the picture cards.

Step 3. Word span task with keywords: At the step of the immediate recall task of keywords presented in the story, SLPs would say between three and six keywords selected from the semantic categories of the story. Participants were then asked to recall the three keywords in order (e.g. grandson, squid, bicycle). When the participants immediately recalled three keywords in sequence, the next span of four words were presented and they were asked to recall them. If the participants failed to recall the words, SLPs systematically provided the following three cues. Firstly, they presented the cards with the name of the semantic category written for the target word (e.g. family, food, transportation) and participants were asked to recall the words again by looking at the semantic category name cards. Although the semantic category name cards were presented, if the participants couldn't recall the words, secondly researchers randomly presented additional picture cards of the target words and asked participants to arrange the picture cards on top of the semantic category name cards presented in Cue 1. In case of an incorrect response in Cue 2, thirdly SLPs randomly presented additional target word letter cards (e.g. grandson, squid, bicycle), and participants finally used semantic classification by sorting out pictures and letter cards corresponding to the correct semantic categories.

Step 4. Semantic category facilitation: SLPs provided letter cards of each of the semantic categories included in the story and asked participants to recall as many words as possible in each semantic category in 30 s. This step aimed to improve both WM and word fluency abilities by recalling words related to target semantic categories, including keywords.

Step 5. Retell the whole story: To develop mnemonic and story strategies, SLPs provided, in order, the keyword picture cards used in the story, and asked participants to retell the entire story from beginning to end with the aid of the picture cards from the 12 keywords. The procedures and instructions for clinicians are included in Table II.

Experimental design and procedures

The current study employed a randomised, single-blind, two-arm parallel-group design with pre- and post-treatment measurements, consisting of treatment and assessment phases. All the experimental procedures, including assessments and treatments, were conducted in person at the dementia support centre. For the assessment phase, both treatment and control groups were administered two consecutive sessions for each pre- and post-assessment to test cognitive and linguistic abilities. The treatment included 10 sessions (lasting approximately 1 hr twice per week) as described earlier. It is noteworthy that all participants in the treatment group attended every session. Pre- and post-assessments were administered by clinicians who did not perform the treatment protocols for either treatment or control groups. The treatment protocol was individually administered to participants assigned to the treatment group by the research assistants, including the second author of the manuscript.

In each treatment session one story was presented as a treated story, and a total of five stories were shown twice during the 10 sessions for the treatment group. While the control group received no treatment, they were exposed to the five stories twice to balance the amount of exposure to the novel stories between the two groups. The scripts were presented

Table II. Discourse-based working memory treatment hierarchy.

Treatment step	Procedure	Clinician instruction
Step 1: Story retelling	Listen to the entire story and immediately retell it. Answer the story comprehension questions.	Listen to the story and tell the story again after listening. Please respond to the story-related questions.
Step 2: Story regeneration with visuospatial cues	Picture cards are presented. Rearrange the picture cards (place, transportation) that clinicians have randomly presented.	Please reorder the locations and transportation cards in the story.
Step 3: Word span task with keywords	Recall the span task consisting of the story's keywords up to spans three to six.	Please recall the words from the story in the order listed.
Step 4: Semantic category facilitation	Category letter cards are presented. Recall as many words as possible with each of the semantic categories letter cards.	Say as many words as possible that fall into the categories on the letter cards.
Step 5: Retell the whole story	Keyword picture cards are presented. Ask participants to retell the entire story.	Tell the whole story with these keyword cards.

in the same order for both groups: going to the market, meeting friends, going on a trip, going on a picnic at the zoo, and getting medical treatment. All participants in both of the groups did not receive any other types of cognitive and linguistic treatment at the time of the treatment and assessment.

Treatment outcome measures

Outcome variables for the pre-post comparisons included IUs and accuracy scores for content-related questions from the five stories used by the treatment protocol. The number of IUs serves as both an index for assessing story retelling performance and a key idea for conveying semantic information (Nicholas & Brookshire, 1993). In this study, IUs were used as both content words and function words to build the sentences in the story. The total number of correct IUs for each participant in each story was calculated by the examiner. Another outcome measure was participant performance (immediate recall, delayed recall, questions regarding the content) of the untreated novel story on the standardised story-retelling tasks from the Elderly Memory Disorder Scale (EMS; Choi, 2007). The immediate and delayed recall score is made up of a total of 30 points, calculated by combining the story units and topic scores. The recognition task consisted of 10 comprehension questions about the story and scored for a total of 10 points. After 20 min of engaging in the immediate recall task, the delayed task was presented followed by the recognition task. The untreated novel story from the EMS was not shown to all participants except for the assessment sessions. The scores of digit forward/backward span tasks (Yeom et al., 1992), word forward/backward span tasks (Sung, 2011), and visuospatial forward/backward span tasks using the Corsi-block from the EMS (Choi, 2007) were used as the outcome variables to measure WM capacity. Finally, the scores of semantic category fluency tasks (animal, supermarket) from the controlled word association task (Kang et al., 2000) were calculated pre- and post- treatment.

Reliability of scoring for the outcome measures

To examine the reliability of the outcome measures, the researcher (JES) trained another rater (SC) on all outcome measure scoring criteria, and the rate of agreement with the researcher were 100%, with 100% of the data being rescored. Following the assessment sessions, the researcher reviewed the session video, recalculated the outcome measure scores, and confirmed the 100% concordance rate.

Data analyses

The distributions of the variables failed to meet the assumption of normality, so we conducted nonparametric permutation tests and Wilcoxon signed-ranks tests for the within-group comparisons between pre- and post-treatment performance for each group. Furthermore, Mann-Whitney nonparametric tests were conducted to examine the differences between the treated and control groups for the post-treatment scores. In addition, we calculated the d-statistics (Beeson & Robey, 2006) as an index of effect size to compare the pre- and post-treatment effects. We present the data in Supplementary Materials 1.

Result

Comparisons of story retelling abilities

Treated story (analyses of information units)

In the within-group comparisons, the results revealed significant differences between pre- and post-treatment assessments in the treated group in the number of IUs, $Z = -2.371$, $p = .018$. The number of pre-treatment IUs of 106.14 ($SD = 60.15$) increased to 192.00 ($SD = 102.19$) after treatment. However, in the control group, no statistically significant differences were found between pre- and post-treatment, $Z = -1.524$, $p = .128$. For the between-group comparisons after treatment, statistically significant differences in the number of IUs were found between each group. The treated group performed significantly better, $Z = -2.108$, $p = .038$, than the control group.

Figure 2 presents within- and between-group comparisons for IUs.

For the accuracy of the content-related questions, significant increases were observed after treatment in the treated group, $Z = -2.201$, $p = .028$, increasing from 13.57 ($SD = 4.61$) for pre-treatment to 18.14 ($SD = 4.10$) after treatment. In contrast, no significant differences emerged between pre- and post-treatment in the control group, $Z = -1.609$, $p = .108$. After treatment, statistically significant differences were found between groups in the accuracy of the content-related questions. The treated group performed significantly better for the accuracy outcome, $Z = -2.313$, $p = .017$, than the control group.

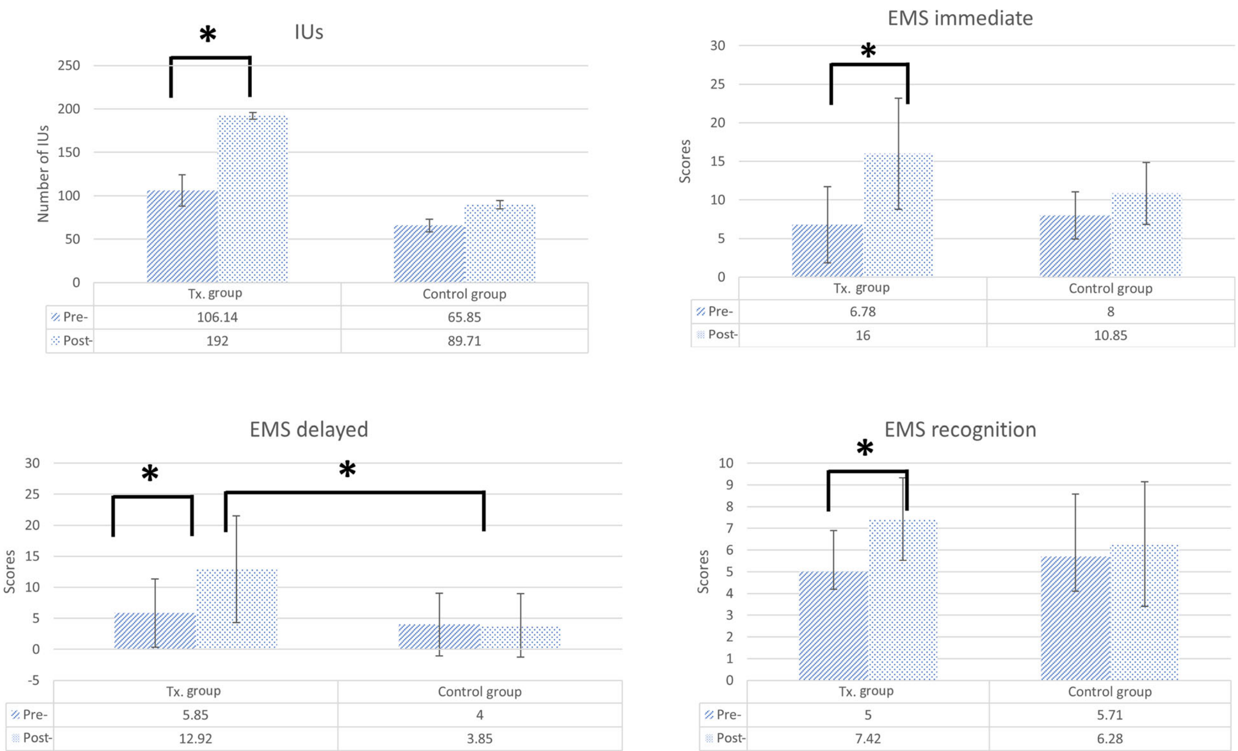
Untreated story (EMS test)

Within-group analyses revealed that the treated group demonstrated significantly better performance on the post- than pre-treatment assessment for this outcome. After treatment, this group had significant improvements in the immediate recall EMS measure, $Z = -2.366$, $p = 0.018$, delayed recall EMS measure, $Z = -2.023$, $p = 0.043$, and recognition recall EMS measure, $Z = -2.207$, $p = 0.027$. In contrast, no significant differences emerged between the pre- and post-treatment assessment in the control group, $Z = -843$, $p = 0.399$. For the between-group analyses after treatment, statistically significant differences were found between groups for the delayed recall EMS measure, $Z = -2.07$, $p = 0.038$ (see Figure 2). There were no significant differences for either the immediate recall EMS measure, $Z = -1.358$, $p = 0.174$, or the recognition recall EMS measure, $Z = -.843$, $p = 0.399$. Figure 2 presents pre-post comparisons within and between each treatment group.

Comparisons of working memory measures

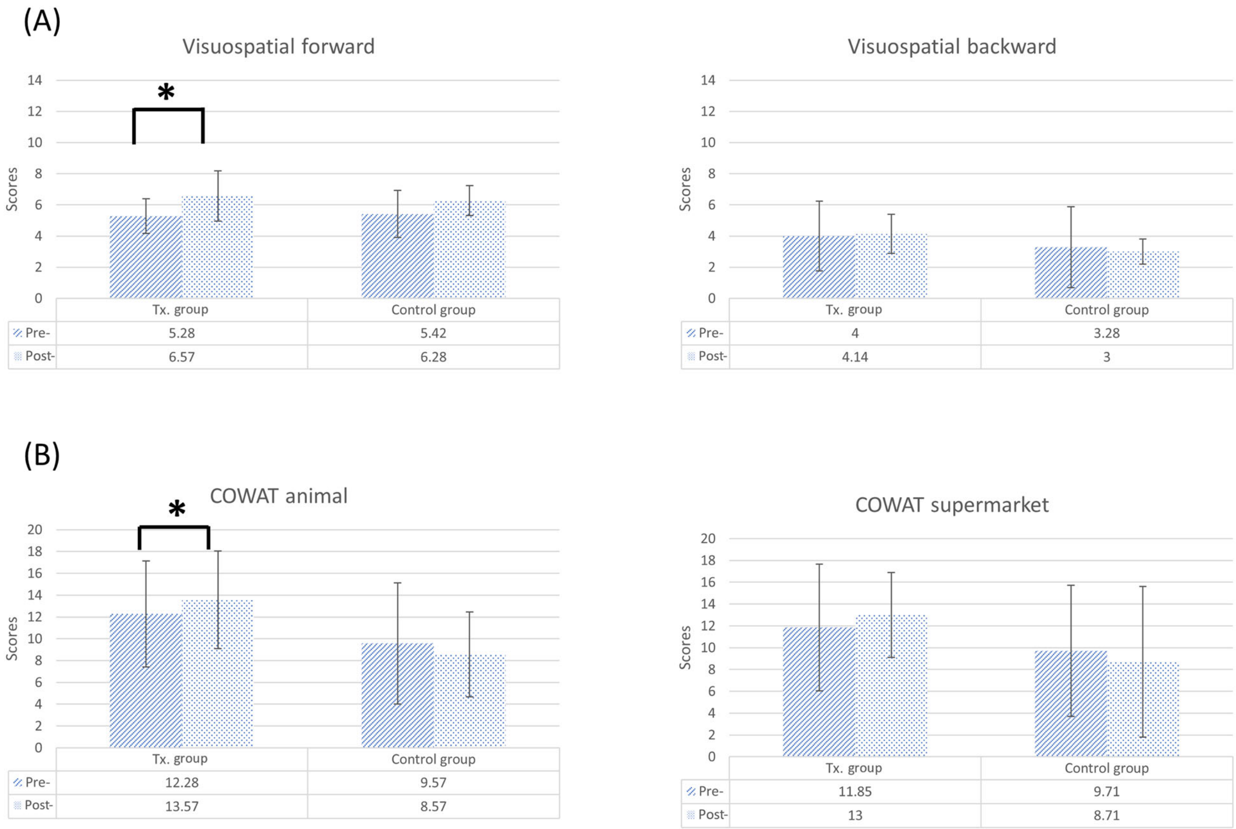
Within-group analyses demonstrated that there were no significant differences in digit- and word-span measures between pre- and post-treatment assessments in either group (in all cases $p > 0.05$). Furthermore, no significant differences emerged from the between-group analyses after treatment: digit-span forward, $Z = -.803$, $p = 0.422$, digit span backward, $Z = -1.58$, $p = 0.114$, word span forward, $Z = -.213$, $p = 0.831$, and word span backward, $Z = -1.271$, $p = 0.204$. We provide specific details of data on the measures in Supplementary Materials 1.

For the visuospatial forward span measures using the Corsi-block from the EMS, the treatment group demonstrated significantly better performance on the post-treatment assessment, $Z = -2.121$, $p = 0.034$. In contrast, no significant changes were observed for the control group in the visuospatial forward span task, $Z = -1.298$, $p = 0.194$. For the visuospatial backward span task, no significant differences emerged in either the treatment group, $Z = -.447$, $p = 0.655$, or the control group, $Z = -.816$, $p = 0.414$. For the between-group comparisons after treatment, there were no significant differences between groups in visuospatial span measures: forward span task, $Z = -.265$, $p = 0.791$ and backward span task, $Z = -.591$, $p = 0.554$. Figure 3(A) presents group comparisons of averages and deviations for visuospatial span measures.



Note: EMS = Elderly Memory disorder Scale(Choi, 2007)
* $p < .05$

Figure 2. Pre-post comparisons within each group and group comparisons of story-retelling abilities.



Note: COWAT = Controlled Oral Word Association Test(Kang et al., 2000)
* *p* < .05

Figure 3. Pre-post comparisons within each group and group comparisons for the visuospatial span measures (A) and controlled word association task (B).

Comparisons of controlled word association tasks

Within-group analyses revealed that the treatment group demonstrated significant improvement after treatment in the semantic category of animal, $Z = -1.936$, $p = 0.05$, but not in that of supermarket, $Z = -.681$, $p = 0.496$. In contrast, the control group did not produce any significant changes in either of the two semantic categories for the pre-post comparisons: animal, $Z = -1.289$, $p = 0.197$ and supermarket, $Z = -.931$, $p = 0.352$. The between-group analyses after treatment did not reveal any significant differences: animal, $Z = .000$, $p = 1$ and supermarket, $Z = -1.415$, $p = 0.157$. Figure 3(B) presents within- and between-group comparisons of averages and deviations for the controlled word association tasks.

Discussion

Efficacy of the discourse-based WM protocol and transfer effects

The current study investigated the treatment effectiveness of a discourse-based WM protocol for MCI using a randomised controlled design. The treatment group demonstrated a significant increase in information units retrieved and performed better in comprehension accuracy after treatment, while the control group remained constant without significant changes in any of the story-retelling outcome measures. These results suggest the potential efficacy of our treatment protocol. The treatment protocol consisted of systematic procedures to facilitate the encoding and retrieval processes of verbal information steps, such as semantic reorganisation and expansion of verbal memory span. The treatment group also had increased performance on the untreated novel stories from the EMS, indicating that the discourse-based WM treatment was transferred to untreated items. However, it is interesting to note that the transfer effects were limited to the immediate recall measures, not to the delayed recall performance. The modality-specific transfer effects are likely due to the mnemonic strategy that the current WM treatment protocol taps into. The current protocol includes keyword-based immediate recall steps (c.f. Step 3 in Table II). This procedure is likely to induce transfer effects to the tasks in which the same strategy is employed. The transfer effects indicate that the MCI group still has the cognitive capacity and flexibility that can accommodate the ability to learn both new information and memory strategies.

The current findings are well aligned with previous studies, which reported that individuals with MCI benefitted from cognitive training programs, indicating that they may retain cognitive plasticity (e.g. Jean, Bergeron, et al., 2010; Jean, Simard, et al., 2010; Law et al., 2022; Olchik et al., 2013; Simon et al., 2012; Yang et al., 2019; Zhao et al., 2022). The effectiveness and transfer effects of behavioural training that taps into various cognitive and linguistic domains carry significant clinical implications. Behavioural treatment programs can be a potentially good alternative as therapeutic approaches for intervention and prevention in older adults at risk (Olchik et al., 2013). Considering that the current treatment protocol heavily focuses on enhancing language-based, verbal recall mnemonic strategies, this prior research supports our observed, significant treatment effectiveness and their transfer effects onto related domains. Especially, in treatment Steps 3 and 5, we composed the hierarchy using the keyword cards from the treated stories to develop and facilitate the mnemonic strategies. However, we caution against interpreting the results of treatment and transfer effects, given that the effects were selectively transferred to certain domains. Furthermore, the results can be limitedly applied to the amnestic type of MCI.

With respect to the transfer effects, the current study found some transfer effects from the verbal to non-verbal domains. For the verbal domains, the treatment group presented transfer effects on controlled word association tasks, which are one of the verbally-mediated measures of frontal lobe executive functions. The results indicate that the discourse-based WM treatment protocol used in the current study may have a positive impact on the frontal lobe functions that specifically tap into verbal functions, such as the semantic word-association measures. The current treatment protocol encompasses linguistic feature-based verbal WM facilitation. Specifically, it uses keyword-based semantic facilitation and WM components by rearranging the semantic categories and systematically connecting the semantic features with information-retrieving strategies. Considering these linguistic components in the protocol, the verbally mediated frontal lobe functions may have benefitted from this facilitation procedure. However, it should be noted that the transfer effects were not observed in the comparisons of digit- and word-span measures from either of the comparisons from forward and backward recall measures. The results suggested that the current WM training program selectively elicited transfer effects onto the verbal domains of the frontal lobe functions. We, therefore, speculate that controlled word association tasks are more closely related to semantic activation than the simple digit- or word-span measures in which participants are asked to recall semantically unrelated random digits or words. Due to the differential features between the two measures of controlled word association measures and digit/word span tasks, the current protocol may elicit differential transfer effects. The treatment features from the keyword-based semantic facilitation steps may induce positive effects on semantically-related tasks that may share a similar semantic activation network, while its transfer effects may be limited to the verbal domains that do not rely on semantic relatedness.

In terms of the transfer effects onto non-verbal domains, we found some significant improvements in the visuospatial WM domain, as measured by the Corsi-block span task, although the significant effects were limited only to the visuospatial forward span measure. These findings are in line with results from Carretti et al. (2013), who reported that WM training effects were transferred to a visuospatial WM task. Carretti and colleagues employed verbal WM span expansion protocols at the word level. Those components are similar to Step 3 of our protocol (word span facilitation using keywords). Facilitating word-span expansion strategies for older adults may contribute to far-transfer effects, but more studies are needed to confirm this hypothesis in order to identify which components of our protocol steps maximise the transfer effects.

Study limitations and future directions

We acknowledge that the current study has a number of limitations. First, the current treatment study is based on a limited sample for each treatment and control group, since it was restricted to the amnestic type of MCI. More studies need to attempt to recruit participants with diverse types of MCI and larger samples in order to validate the WM protocol that is specifically designed to tap into the semantic activations of verbal strategies in the WM treatment. Second, we did not conduct a treatment fidelity study for the intervention. The current treatment protocol is scripted with very specific guidelines provided for clinicians, who were extensively trained prior to the implementation of the protocol. Future studies need to report the fidelity of the treatment to improve the overall quality of evaluating the clinical evidence for the success of the treatment.

To date, there is increasing evidence of the effects of WM training as a potentially very powerful and influential method to prevent or delay the progression of neurodegenerative disease. The current WM training program is novel in that the WM training components are embedded within a conversational-level story construct, in which participants were trained to retrieve the semantic features more efficiently by expanding their memory span. The current protocol elicited some treatment and transfer effects despite several limitations. The results suggest that this linguistic-cognitive, interactive, WM training program needs to be further replicated and examined with different MCI subtypes to validate its potential. Future studies need to further investigate the maintenance effects over a longer period. Furthermore, more studies are required to determine the most appropriate treatment dosage that produces optimal effectiveness as behavioural therapy for people with MCI. To this end, logging the trajectory of performance across sessions or stories can provide a more detailed understanding of the development and transfer of participants' linguistic skills over time. Identifying the optimal dosage and frequency of treatments can inform future clinical practices and promote the desired treatment and transfer effects. Considering that pharmacological therapies are limited to people at the very early stage of dementia (Birks & Flicker, 2006; Russ, 2014), behavioural treatment approaches may serve as a potentially effective therapy for ageing populations at risk. These clinical implications of this research suggest that a discourse-based WM training program is a potentially good candidate for enhancing the cognitive reserve and linguistic networks of individuals with MCI.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was partly supported by the National Research Council of Science & Technology (NST) grant by the Korea government (MSIT; No. CAP21053-000), the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT; 2022R1A2C2005062), and the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2022R1I1A4063209).

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