The Impact on Working Memory of the 4-D Multiple Resource Model as Embedded in Interpretation Training

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Abstract

Working memory, the mental ability to temporality store and process information, is essential in both daily and academic life. This study aimed to compare the effect of an interpretation training program, based on the 4-D Multiple Resource Model, on working memory in the experimental group according to pre- and post-training scores, and to compare the effect on working memory in the active control group versus the experimental group according to post-training scores. Sixty undergraduate students enrolled in English II at Khon Kaen University were randomly assigned into either an experimental group or an active control group. The experimental group completed sixteen sessions of interpretation training, 30-45 minutes each, via a website, while the active control group practiced using metacognitive strategies. A listening span task for L2 learners and a dual n-back task were employed as pre-post measures for assessing working memory capacity. Compared with the active control group, the experimental group's working memory capacity after the training improved markedly ($p < .05$). Thus, it is concluded that interpretation training that exploits a variety of attentional resources and taps various working memory components could be applied toward enhancing working memory.

Keywords: Cognitive Training, Attentional Resources

Introduction

The everyday life of humans is full of information, different tasks to complete, and numerous goals to achieve. For example, once one has found the telephone number for ordering food on the Internet, they must rehearse the number in their mind before dialing it. Working memory, a mental ability to temporarily store and process information, is essential for human cognition, including in multitasking (Hambrick, Oswald, Darowski, Rench, & Brou, 2010) and intelligence (Wongupparaj, Kumari, & Morris, 2015). For educators, working memory is a highly accurate index of academic and professional achievement (Alloway & Alloway, 2010), and importantly, scientific evidence supports that working memory is trainable (Klingberg et al., 2005).

The rise of cognitive training has been boosted by the concept of brain plasticity. Rather than being static, the human brain has been shown to have the ability to adapt its structure and functions in order to fit into changing environments. For example, the hippocampus has a role in assisting spatial memory. The posterior hippocampi of taxi drivers, who heavily rely on their spatial memory to find their way from one place to another, are larger than those of people who do not drive taxis (Maguire et al., 2000). Similarly, the concept of brain plasticity has been adopted by braining training enthusiasts, especially working memory training, because working memory is a fundamental cognitive ability related to language comprehension, learning, intelligence, reasoning, and so on. As working memory is essential for humans, several working memory training programs, such as CogMed, Jungle Memory, and Cognifit, have been created throughout the last decade for commercial purposes. The currently available training methods, however, based on psychological tasks, are unrealistic (Holmes & Gathercole, 2014; Moreau & Conway, 2014), and the concept of brain plasticity has been somewhat overused. The search for an alternative method for training working memory must be concerned with theoretical frameworks underpinning working memory.

The multi-component model (Baddeley, 2000) has been one of the most influential models of working memory. The model consists of two slave components, a central executive, and an episodic buffer. The slave components are the phonological loop, as a temporary storage of verbal information, and the visuospatial sketchpad, as a temporary storage of visual and spatial information. The central executive plays a managerial role in coordinating the slave components, while the episodic buffer is a modality-free storage responsible for integrating the information with different modal codes. Another influential model of working memory is the embedded processes model proposed by Cowan (1988). He claims that the architecture of human memory has only one system, long-term memory, which is influenced by different levels of attention. In this model, long-term memory is divided into three main areas. One part is in an inactive state while the other two are activated. Within the activated area, the highly activated area is represented by the focus of attention, which becomes a mechanism of working memory. The central executive dominates the focus of attention (Cowan, 2005). After Baddeley added the episodic buffer to his multi-component model, the two models became rather similar. Cowan speculates that the only difference is, “the level of analysis: a level of specific phonological, visuospatial, and episodic storage properties versus a level of general principles of activated memory and attentional focus” (Cowan, 2005, p. 48). Based on these two models of working memory, attention plays its role side by side with working memory. In the multi-component model, the central executive, further developed from its role as supervisory attentional system (Norman & Shallice, 1980), is responsible for directing attention (Baddeley, 1996; Baddeley, 2002). Meanwhile Cowan (1999) claims that the activated area of long-term memory becomes working memory when activated from the attentional focus directed by central executive. What both models imply is that an alternative method for training working memory should involve the use of both working memory and attentional focus.

Better performance of working memory can be induced by enhancing its capacity. In order to improve working memory, it must be stimulated by a higher cognitive demand than its current limits. This can affect adjustments in the brain area (plasticity), which determines working memory capacity (Lövdén, Bäckman, Lindenberger, Schaefer, & Schmiedek, 2010). Interpreters juggle at least two languages, and they also listen and speak simultaneously. Moreover, interpreters are required to divide their attention to surrounding stimuli with different modalities, such as a speaker’s facial expressions, tone of voice, or a PowerPoint presentation, and they must integrate the information they hear before rendering ideas or messages into the target language (TL). This extreme cognitive demand leads to brain plasticity, such as an increase in cortical thickness in the brain areas responsible for assisting working memory (Hervais-Adelman, Moser-Mercer, Murray, & Golestani, 2017) and an increase in GM volume in the brain center, helpful for semantic processing, executive functions, and error monitoring (Hervais-Adelman, Moser-Mercer, & Golestani, 2011). According to the evidence, interpretation training is a promising task for improving working memory.

Objective

To investigate the effectiveness of an interpretation training program on improving working memory in the active control group versus the experimental group according to pre- and post-training scores, and to compare the effect on working memory in the active control group versus the experimental group according to post-training scores

Conceptual Framework

The interpretation training program for improving working memory delivered a variety of attentional stimuli embedded in the interpretation training activities, resulting in different levels of attentional interference. Working memory: storage and processing capacity, would reach its best endeavor to manage attentional resources, and to store linguistic information temporarily. This would lead to working memory gain.

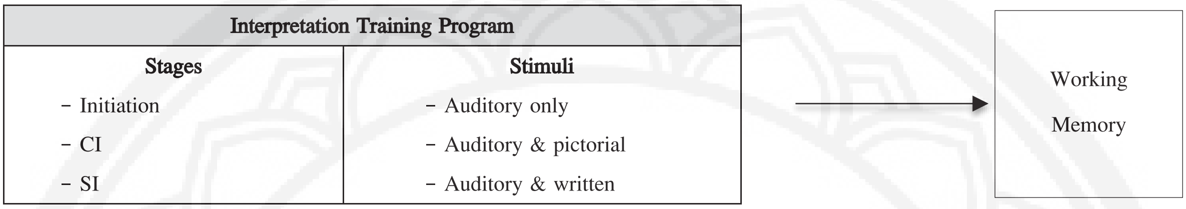

Figure 1 Working Memory

Methods

Participants

The participants of this study were Thai undergraduate students majoring in fields of Humanities and Social Sciences and enrolled in English II at Khon Kaen University during the second semester of the academic year 2018. Purposive sampling was used to select the students, who were Threshold (CEFR level B1) language users, aged 18-19. The participants did not report any significant hearing impairment. Sixty participants were randomly assigned into the experimental group or active control group, each group being assigned thirty participants. By the end of the training, 55 participants had completed all required tasks: 28 participants in the experimental group (male = 4 (14.29%), female = 24 (85.71%); aged 18 = 3 (10.71%), 19 = (89.29)) and 27 participants in the active control group (male = 6 (22.22%), female = 21(77.78%); aged 18 = 4(14.81%), 19 = 23(85.19%)).

Research Tools

1. Interpretation Training Program

The program based on interpretation training pedagogy (Setton & Dawrant, 2016) had three main consecutive training stages: Initiation (4 minor stages), Consecutive Interpretation (CI, 6 minor stages), and Simultaneous Interpretation (SI, 6 minor stages). Multiple resource theory (Wickens, 1984) was employed in deciding the number of memory loads. The four minor stages in Initiation were aimed at preparing the participants' working memory, including the phonological loop and visuospatial sketchpad, preparing them for completing the more difficult or demanding tasks in the CI stage. Each trial of Initiation had two phases: the learning phase and memory phase. In the learning phase, confusing auditory word pairs, such as *lock* and *log*, and pictures depicting the meaning of the auditory words were introduced to the participants. In the memory phase, participants heard a series of auditory words. Then, the participants verbally answered an unrelated question presented on a computer screen in order to obstruct their mental rehearsal, and finally they selected the correct choice of what they had previously heard. Also, an auditory word with modifications, such as a bag, a pink bag, and a yellow bag was accompanied by pictures representing the modified words positioned at four different locations on the screen. After answering an unrelated question, the participants, in the memory phase, heard a modified word and recalled the spatial information of the picture representing the word they had heard.

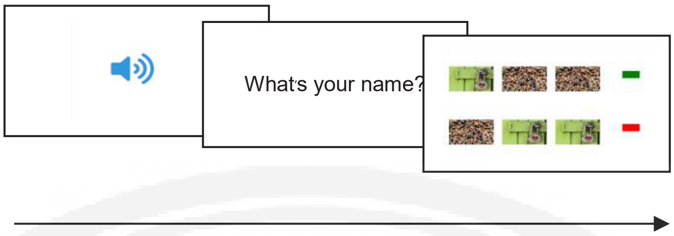

Figure 2 The Memory Phase in Initiation

In the CI stage, each trial had three phases: interpretation, Q & A, and feedback. Regarding the interpretation phase, participants were asked to interpret after the source language (SL) sentence had ended. Next, unrelated question(s) with four choices on an orange background were followed by question(s) related to what the participants had heard in the interpretation phase, presented with four choices on a white screen. At the end of each trial of CI stages, suggested interpretation to Thai was provided and the participants had to recall their interpretation in order to get feedback from the program, checking the boxes under the Thai interpretation. A summary of what they had missed was provided. At higher stages, sentences were presented in a conversational format.

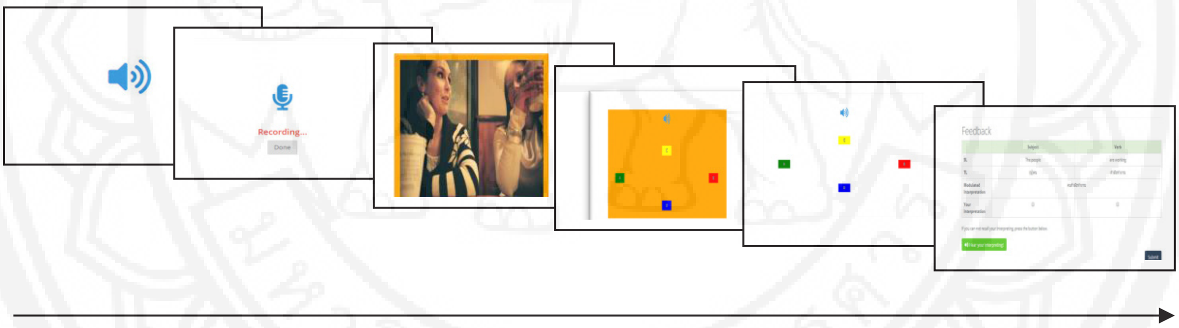

Figure 3 An Example of a CI Trial: Listening Comprehension & Interpretation, An Unrelated and Related Question, and Feedback

Next, the SI stage delivered concurrent presentation of auditory and pictorial stimuli, or auditory and written stimuli, imposing the highest level of cognitive load of all three stages. In conducting SI, the participants were required to listen to an auditory stimulus in English, look at pictures or written information on a computer screen for additional information related to the auditory stimulus, and simultaneously render the English stimulus into Thai. The SI stage also had Q & A and feedback phases.

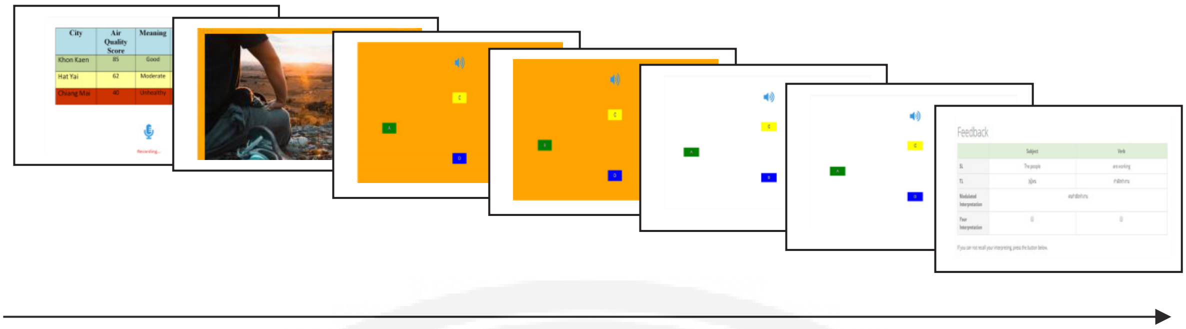

Figure 4 An Example of an SI Trial: Listening Comprehension & Interpretation, Two Unrelated and Two Related Questions, and Feedback

Employing a no-contact control group might cause a placebo effect owing to a failure to control for different levels of expectations between an experimental group and a no-contact control group. Therefore, the active control group was integrated into the study. Based on L2 listening studies during the past decade, metacognitive strategies have received much attention from Thai researchers. For the reason, metacognitive strategy training was presented to the active control group. Metacognitive strategies refer to the ability to monitor and manage one's thinking process. In L2 listening, metacognitive strategies include planning, monitoring, evaluating, and problem solving (Vandergrift, 2008). In a classroom setting, the participants in the active control group underwent a metacognitive strategy training, using the same auditory stimuli as in the interpretation training program.

2. Listening Span Task for L2 Learners

The frequently-used listening span task in English would not appropriately reflect participants' mental ability to temporarily maintain and process information, given that they were L2 learners with English proficiency at B1 level; therefore, a listening span task for L2 learners was created. The aim of the listening task was to measure storage and processing capacity of working memory by requiring the participants to comprehend each auditory sentence and decide whether the sentence was possible while remembering the ending word of the sentence. Vocabulary for forming sentences was selected from the KET Vocabulary List for CEFR level A2, a level lower than B1, to increase comprehensibility of the sentences. Four sets of sentences: including a set of two, three, four, and five sentences were presented in respective order. The sets of sentences were rendered by a non-native speaker of English, and the listening span task was delivered through PowerPoint presentation slides. The task was evaluated by two experts in cognition and three experts in applied linguistics to investigate content validity according to two aspects: the general features of the task (4 items) and the language stimuli in the program (6 items). The scale-level index with averages of the item-level CVIs (S-CVI/Ave) was 0.98, indicating excellent content validity. Convergent validity was also investigated by correlating the listening span task for L2 learners with the operation span task widely used for assessing working memory absent language barriers. Based on Pearson's coefficient, r was .849, p = .000, signifying that the two tasks had a high correlation.

3. Dual N-Back Task

The dual n-back task concurrently presented to participants two stimuli with different modalities, including letter and position. When a stimulus matched the one that appeared **n** items back in the series, the participant had to either press the button or ignore it in the mismatch condition. The value of **n** increased from one-back to three-back for each block of trials. The Psychology Experiment Building Language (PEBL), a free open-source software system, delivered the dual n-back task (Mueller & Piper, 2014).

Procedures

Procedures for this study comprised a pretest session, a training session, and a posttest session. After the screening process, which considered English language proficiency, field of study, age, and hearing impairment, participants received a vocabulary manual one week prior to the pretest session. Participants' initial working memory capacity was assessed using the listening span task for L2 learners delivered via PowerPoint presentation and the dual n-back task delivered through the Psychology Experimental Building Language computer program (Mueller & Piper, 2014). Then, the participants in the experimental group partook in all 16 stages, 35-45 minutes each, of the interpretation training program. All interpreting tasks were presented on a Lenovo Thinkpad personal computer with a 15.4-inch screen (maximum resolution 1680 x 1050) and Microsoft Windows XP Professional as the operating system. The participants in the active control group were exposed in a classroom environment to the same stimuli used in CI and SI stages. They were given a lecture on metacognitive strategies and encouraged to use the strategies in completing the tasks. The listening span task for L2 learners and the dual n-back task were utilized again in the post-training assessment.

Data Analysis

To describe basic features of the collected data, descriptive statistics were obtained on the data using SPSS, including mean score, standard deviation, and frequency distributions. Basic assumptions were investigated prior to performing the independent t-test twice in order to compare the mean scores of the listening span and dual n-back tasks between the two groups and for both the pre- and post-training sessions.

Results

Table 1 Pre-Training T-Test

	N	Mean	SD	df	t	*p*
Listening Span Task for L2 learners						
Experimental Group	28	.81	.08	53	.92	.36
Active Control Group	27	.79	.08			
Dual N-Back Task						
Experimental Group	28	.65	.08	53	.83	.41
Active Control Group	27	.64	.08			

Basic assumptions were not violated. According to Table 1, the results show no significant difference in working memory capacity as assessed by the listening span task for L2 learners (p = 0.36 (2-tailed), t (53) = 0.92, $p > 0.05$) and the dual n-back task (p = 0.41 (2-tailed), t (53) = 0.83, $p > 0.05$) between the experimental group and active control group prior to the training. That is, the two groups were approximately the same in terms of working memory capacity prior to the training.

Table 2 Pre-and Post Training Paired T-Tests

Experimental Group	N	Mean	SD	df	t	*p*
Listening Span Task for L2 learners						
Pre-training	28	0.81	0.08	27	7.63***	0.000
Post-training	28	0.89	0.05			
Dual N-Back Task						
Pre-training	28	0.65	0.08	27	8.34***	0.000
Post-training	28	0.75	0.04			

According to 2, the results from the listening span task for L2 learners (p = .000 (2-tailed), t (27) = 7.63***, p < 0.001) and the dual n-back task (p = .000 (2-tailed), t (27) = 8.34***, p < 0.001) indicate a significant difference between pre- and post-training scores achieved in the experimental group for working memory. The results revealed the improvement of working memory in the experimental group after the interpretation training.

Table 3 Post-Training T-Test

	N	Mean	SD	df	t	*p*
Listening Span Task for L2 learners						
Experimental Group	28	.89	.05	53	4.10**	.00
Active Control Group	27	.82	.07			
Dual N-Back Task						
Experimental Group	28	.75	.04	53	3.85**	.00
Active Control Group	27	.69	.06			

As shown in Table 3, the results from the listening span task for L2 learners (p = .00 (2-tailed), t (53) = 4.10**, p < 0.01) and the dual n-back task (p = .00 (2-tailed), t (53) = 3.85**, p < 0.01) indicate a significant difference between the groups' working memory capacity after the training. After the training, the experimental group's scores from the listening span task for L2 learners, with Mean = 0.89, SD = 0.05, and the dual n-back task, with Mean = 0.75, SD = 0.04, show higher levels of working memory capacity than the active control group's scores from the listening span task for L2 learners, with Mean = 0.82, SD = 0.07, and the dual n-back task, with Mean = 0.69, SD = 0.06.

Discussion

This study aimed to improve working memory through interpretation training, which required the participants to concurrently deploy working memory and attentional resources. The results from the pre-training assessment revealed no inherent advantage on working memory between the experimental group and the active control group. As predicted, the participants in the experimental group, compared with the active control group, showed significantly higher scores in both the listening span task for L2 learners and the dual n-back task. The marked improvement in working memory could potentially result from the extreme cognitive demand required in completing the interpretation tasks. In the Initiation stages of the training program, the interpreting tasks required the participants in the experimental group to familiarize themselves with the auditory stimuli, posting memory loads on the phonological loop. Visual and spatial stimuli were also prepared for exercising the visuospatial sketchpad. Moreover, auditory stimuli and visual stimuli were presented in similar groupings, requiring the participants to pay close attention to the stimuli. Both CI and SI interpretation modes required the participants to divide their limited attention in order to process and complete the interpretation tasks, thus burdening working memory (Cowan, 1995; Gile, 2008).

Two working memory measures were employed in this study. The first one was a listening span task requiring the participants to temporarily store an ending word of each sentence in their storage capacity of working memory while the processing capacity was responsible for comprehending the sentence to judge the plausibility of each sentence. The other was a dual n-back task taxed not only storage and processing capacity but also the updating components of the tripartite model of EFs (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). The following section was provided to explain the reason why the interpretation training program would affect the storage and processing capacity, and updating.

In each trial of CI stages, the participants had to listen to a sentence in the SL, wait until the sentence ended, maintain the idea in their mind, and deliver the idea in the TL. Clearly, the storage component of working memory was heavily used for memorizing and maintaining the auditory stimuli. In his Effort Model, Gile (2009) provides two formulas representing two stages and the cognitive components involved in completing CI tasks. They are:

(1) Comprehension Phase: L + M + NP + C

L: Listening, M: Short-term memory, NP: Note Production, C: Coordination

(2) Reformulation Phase: NR + SR + P + C

NR: Note Reading, SR: Speech Reconstruction from Memory, P: Production, C: Coordination

Professional interpreters reduce working memory loads by taking notes, trying to capture only key words or phrases to help them recall when they deliver the SL into the TL. However, the CI tasks in this study's interpretation training program did not allow the participants to take notes while listening. Without cognitive assistance from notes, the storage capacity, or short-term memory, and central executive have a more prominent role in completing the training program's CI tasks. This extreme use of the storage components of working memory could be one of the factors yielding an improvement in working memory capacity.

A central executive that processes more efficiently may also lead to better working memory scores. The central executive must fulfill executive functions (Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001), including updating, inhibition, and shifting (Miyake et al., 2000). Updating abilities have evidently been enhanced in previous studies aiming to investigate the effects of CI and SI training on working memory. In a longitudinal study by Dong, Liu, & Cai (2018), CI training compared with general L2 learning, was more effective in improving updating efficiency. Moreover, better updating function has been observed among simultaneous interpreters when compared to ordinary bilinguals (Morales, Padilla, Gómez-Ariza, & Bajo, 2015). The possible reason for the improved efficiency in updating is that the interpretation training required the participants to listen to the TL, collect pieces of linguistic information, update (recall) the previous pieces of information that had been in the focus of attention, and verbally convey all information in the TL. Both CI and SI tasks in the interpretation program required the same process, but the SI tasks required a faster processing speed. The process was similar to the dual n-back task, which had the participants recalling **n** items back. In terms of attentional focus, the interpretation tasks in the CI and SI stages simulated what professional interpreters have to do in their career, with participants shifting their attention from listening to speaking and vice versa. Moreover, they had to divide their attention to support their listening of both the SL and their own voice when speaking in the TL, resulting in the built-in cognitive loads recruiting more attentional resources. Dividing their attention throughout the interpreting tasks prepared the participants for the computerized dual n-back task. As the name of the task implies, the dual n-back task involved two types of stimuli, letter and spatial information, concurrently presented to the participants in independent sequences. The finding of this study is in accordance with previous attentional studies of dual- or multi-tasks. In a study conducted by Stachowiak (2014) using the dual-task paradigm, interpreters outperformed late bilinguals in their reaction times. Similarly, in dichotic listening, simultaneous interpreters outperformed non-linguistic experts in performing free recall, while consecutive interpreters were better at ignoring unwanted information (Hiltunen, Pääkkönen, Vik, & Krause, 2016).

In summary, the present study seems to confirm that better working memory is developed through training in interpretation in the two modes: CI and SI.

Recommendations

Concerning the implications of this research, teachers in foreign language classrooms should encourage their learners to interpret reading or listening from the SL to the TL. Interpretation activities may be included in materials that aim to improve learners' proficiency. Cognitive improvement would be apparent in the long run.

As for expanding the scope of this study, more research is necessary to investigate the durability of the improvements on working memory that resulted from the interpretation training, as well as the far transfer effects, such as improvements in fluid intelligence. To confirm the research results, advanced research tools, such as an electroencephalogram, should be employed.

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