The Causal Model of Working Memory Capacity

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Abstract

Working memory capacity (WMC) refers to the capacity of working memory, the ability to maintain, manipulate, and access mental representations as needed to support complex cognition. WMC varies widely across individuals and predicts higher-order cognitive abilities, which influence academic achievement in the domain of mathematics and science learning. If we understand the causal model of WMC, we can enhance the academic achievement. Currently, there is less study on Thai student’s WMC. There were nine observed variables. Data were collected from 212 students, grade 7th - 12th, using Computerized Battery Test1 (CBT1) to measure recognition, attention and working memory while doing simple tasks, and using Computerized Battery Test2 (CBT2) to measure WMC. The data were analyzed by the M-Plus Statistical Modeling Program. The results showed that The causal model was fitted with the empirical data ($\chi^2 = 0.241$, RMSEA = 0.03, CFI = 0.976, TLI = 0.963, SRMR = 0.048). The guide can be developing WMC of Thai children.

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1. Introduction

Working memory capacity (WMC) varies widely across individuals and reliably predicts higher-order cognitive abilities that influence academic achievement (Lawson, E.A., 2006). WMC refers to the capacity of working memory. Working memory is the ability to maintain, manipulate, and access mental representations as needed to support complex cognition. The capacity of working memory can be measured. Most researchers use reading ability, visual-spatial ability and operated ability to be the indicators of WMC. (Alonso, D.L., 1998; Mary, H. & Maria, K., 1999; Nash, U., Richard, P. H., Josef, C. S., Randall, W. E., 2005; Behzat, B., 2006; Frank, R.V., William, E.T., James, J. J. & RuSan, C., 2007; Helier, J. R., 2011; Srikoon, S., 2012a; Srikoon, S., 2012b;). Reading ability is the ease in which text can be read and understood. Various factors to measure readability have been used, such as speed of perception, perceptibility at a distance, perceptibility in peripheral vision, visibility, the reflex blink technique, rate of work (e.g., speed of reading), eye movements, and fatigue in reading. (Frank, R.V., William, E.T., James, J. J. & RuSan, C., 2007; Srikoon, S., 2012a). Visual-spatial ability is one aspect of the cognitive functions.

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It is ability to mentally manipulate 2-dimensional (geometric model of the planar projection of the physical universe; length and width) and 3-dimensional (a geometric 3-parameters model of the physical universe; length, width, and depth (or height)) figures. (Alonso, D.L., 1998). Visual-spatial ability is used extensively in mathematics (Mary, H. & Maria, K., 1999; Behzat, B., 2006; Helier, J. R., 2011) including geometry problem-solving logical thinking, mathematics performance and kinesthetic graph, etc. (Behzat, B., 2006). The last, operated ability is ability to solve a series of math operations while trying to remember a set of unrelated words. The participants saw one math operation–word string at a time, centered on a computer monitor. (Nash, U., Richard, P. H., Josef, C. S., Randall, W. E., 2005). Many studies found that there are many factors affecting on WMC including attention, recognition memory and working memory. (Alonso, D.L., 1998; Daryl, F.; 2008).

Attention may be defined as the selective enhancement of some behavior at the expense of other behavior. It is involved in the selective directedness of our mental lives. The nature of this selectivity is one of the principal points of disagreement between the extant theories of attention. Some of the most influential theories treat the selectivity of attention as resulting from limitations in the brain's capacity to process the complex properties of multiple perceptual stimuli. (Colombo, J., 2000). Most empirical studies of attention concentrate on the nature, control and consequences of selection. Models of selective attention have largely focussed on the idea that there might be limited computational resources available to process inputs and choose and execute courses of action. Selective attention is usually conceived as a response to these constraints, in which all but the most important or relevant stimuli for a task are filtered out. This might occur in conjunction with a serial processing strategy in which different stimuli are selectively attended in turn, and the results of processing each are stored in memory. (Peter, D., Sham, K. and P. Read M., 2000). So the relation between attention and working memory are the ability to selectively process information (attention) and to retain information in an accessible state (working memory). (Daryl, F., 2008).

Recognition memory has been defined as the ability to assess accurately that a stimulus has been encountered before. There can be direct recall, which is the ability to remember a stimulus in the absence of that stimulus. There can also be discrimination components in which the learner may be able to distinguish between a stimulus that had been previously presented and a new stimulus, without any further knowledge of either one. Many cognitive neuroscientists believe that these characteristics split recognition memory into 2 interlocking components that have been assigned to unique neurological substrates (John, J. M., 2008). One is formally termed recollection. This involves remembering discrete details about an experience to which the learner has been previously exposed. Several years ago a group of researchers proposed that these behaviors were centered in the hippocampus. Their ideas were largely based on neuroimaging case studies involving individual patients with amnesia. Such assignments became the investigational womb from which a great deal of research—and subsequent data—emerged. The second component, formally termed familiarity, is a stripped-down version of the first. This involves the conscious awareness that some object has been encountered before, but without an ability to recall anything further about it. The group of researchers mentioned previously proposed that these behaviors originated in the perirhinal cortex, a region next to the hippocampus. Both regions are part of the medial temporal lobe memory system, whose full complement includes the parahippocampal gyrus; carrying parahippal, entorhinal, and perirhinal cortices, as well as the hippocampus, subiculum, and dentate gyrus. All are involved in various aspects of declarative memory formation influencing working memory. (Yasuaki, S. & Bradley, C. L., 2004).

Working memory originated from earlier models of short-term memory, one of the most influential frameworks for working memory in cognitive science. The updated model (Baddeley, A.D. 2007) assumes an attentional control system, the central executive, and three storage subsystems, the phonological loop, the visuospatial sketchpad, and the episodic buffer. The phonological loop holds verbal and acoustic information. The sketchpad holds visual and spatial information. The episodic buffer forms an interface between long-term memory, the other storage systems, and the central executive. It is assumed to provide a common coding mechanism (i.e., a common “language”) for the exchange and manipulation of information from different modalities. It may serve as a basis for a temporary and flexible work-space in which diverse information can be combined into meaningful chunks under the attentional control of the central executive. The episodic buffer, like the phonological loop and the visuospatial sketchpad, is limited by the number of chunks of information it can maintain. (Baddeley, A.D., 2007).

Many studies suggested that working memory is very important in academic learning (Dehn, J.M., 2008). There are some educational neuroscience research in Thailand to promote science learning outcomes (Wattanathorn, J., et al., 2008; Kaewkraisorn, N., et al., 2010; Ratthanawongsa, J., et al., 2011; Wangphomyai, P., et al., 2011; Srikoon, S., 2012a; Srikoon, S., 2012b). Since WMC is the capacity of working memory, it should be one factor...
that influences academic achievement too. Enhancing WMC may enrich academic achievement. The effective way to promote WMC is to understand its causal model. So, this study aimed to examine the causal model of WMC.

2. Material and Method

2.1 Samples
One large school in the Northeast in Thailand, one class in the each 7th-12th grade were random selected to be samples. In this survey research, data were collected during 1st-30th December 2011.

2.2 Materials and Measures

2.2.1 Computerized Battery Test1 (CBT1) is comprised of sixth tasks. They are word recognition task (WR) and picture recognition task (PR) to measure the quality of recognition, choice reaction task 1 (CR1) and digit vigilance task (DVT) to measure the quality of attention, stoop task (ST) and rapid visual information processing task (RVIP) to measure the quality of working memory. All tasks are used via the computer.

2.2.2 Computerized Battery Test2 (CBT2) is comprised of three tasks. They are Operated Ability Task (OAT), Reading Ability Task (RAT), Symmetry Ability Task (SAT) to measure the quality of WMC. These tasks are used via the computer, too.

2.3 Analyzing Data

Structural equation modeling (SEM) is a technique used for specifying and estimating this model of linear relationships among variables. This technique is a family of statistical techniques permitting researchers to test such models and as a hybrid of factor analysis and path analysis that researchers can test hypothesized relationships between constructs. (Judea, P., 2011)

3. Result

The causal model of working memory capacity have been adopted to test the causal of constructs variables with the structural equation modeling (SEM).

![Figure 1](image)

**Figure 1** The causal model of working memory capacity (*p<0.05, **p<0.01)

Model tested are displayed in Figure 1. This model indicates an excellent fit with \(\chi^2\) statistic of 27.356 (degrees of freedom = 23, \(p = 0.241\)), with the \(\chi^2/df\) ratio having a value of 1.189 indicates a good fit. The comparative fit index (CFI) is 0.976, and Tucker-Lewis coefficient (TLI) is 0.963 which is more than 0.9 shows
excellent fit. Root mean square error approximation (RMSEA) is 0.030 indicates a good fit. Standardized Root Mean Residual (SRMR) is 0.048 indicates a good fit, too. The highest variation percentage, R-squared value is 0.570.

4. Discussion
This research showed that the causal model was fitted with the empirical data. In detailed, there was significantly effect from recognition on working memory and working memory on working memory capacity but could not prove the significantly effect from attention on recognition. Thus, If you have recognition memory, then will do working memory correctly, if you can do working memory correctly, then will do working memory capacity correctly but more or less attention did not make a change in recognition memory. From this study, one way to promote WMC is focusing on training recognition memory and working memory.

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6. References
