The Psychometric Structure of Working Memory: An Analysis Utilizing Network Modeling

Kevin P. Rosales, Jason F. Reimer, Dylan M. Diaz, Stephanie Canchola, Jonathan Martinez, Lissette Melendez, Laila Delgado, Brandon Garibaldi, Elloy Ponce, Anthony P. Nalvarte, Domique Wheeler & Jazmin M. Mier

Introduction

Working memory (WM) is the ability to actively maintain and manipulate information in the service of complex cognition [1]. Historically, there have been numerous concepts in the field of WM [2], some of which have been formalized as cognitive models [3-4] and others as psychometric models [5]. Given the numerous definitions of WM, it is important to examine which components of WM are most important to assess in measurement models of WM. To this date, the vast amount of research in the WM field has identified four total components of WM: attention [5], verbal short-term storage [6], spatial short-term storage [6], and long-term memory retrieval [7]. Surprisingly, up this point, there is no psychometric model that accounts for all four components in one unified WM model. Moreover, most of this work has been carried out using traditional latent variable modeling techniques [8-9]. Recent research has proposed a novel alternative psychometric technique that can be useful for studying cognitive abilities, namely, network analysis. Network analysis holds several advantages of latent variable modeling both statistically and theoretically [10]. Thus, the goal of the present study was to examine the psychometric structure of WM by incorporating measures of attention, verbal short-term storage, spatial short-term storage, and long-term memory retrieval using network analysis. Doing so, bridges the gap between cognitive and psychometric models of WM.

Methods

Participants

A total of 93 adult participants (22 males, 71 females) were recruited via a research management system (SONA) from California State University, San Bernardino. Participants were provided with extra credit for their participation. All participants were treated in accordance with the APA ethics code and principles.

Materials

Attention	**Antisaccade:** Participants respond to a stimulus that appears on one side of the screen while ignoring a a stimulus that appears on the opposite side; 56 trials total. **Color selective visual arrays**: Participants view an array of blue and red rectangles in varied orientations and, after a brief delay, indicate if a probed rectangle's orientation has changed across 120 trials. **Color stroop**: Participants respond to words displayed in either congruent or incongruent font colors across 288 trials, the primary measure is the average response time of the final four reversal points.
Verbal STM	**Letter span task:** Participants view and verbally name sequences of three to eight letters, recalling each sequence on a response sheet where they write each letter in its correct position, across 18 sets. **Digit span task:** Participants view and verbally name sequences of three to nine digits, then recall each sequence by writing the digits in correct order
Spatial STM	**Corsi Blocks:** The Corsi block task assesses spatial memory by having participants watch a sequence of blocks light up on a grid, then recall and reproduce the sequence by tapping the blocks in the same order.
LTM Retrieval	**Word-word:** In the word-word task, participants learn two blocks of 20-word pairs with recall requiring them to type the missing word after completing a 3-minute intervening task to prevent working memory retention. **Letter-position:** In the letter-position SM task, participants learn two blocks of 12 letter-to-grid position associations), then complete a 3-minute intervening task before recall, where they type the missing letter or position as prompted, without a time limit.

Procedure & Design

All participants completed a total of fourteen tasks across 3 sessions (1 hour each) of which data for their performance on eight of the tasks was analyzed for this study. The order of the tasks was randomized for each participant.

This study utilized a correlational design that incorporated network modeling for analyses. A model optimization process was conducted on both types of network models, in which the models are pruned by a step-down search process with a significance level of .01 in a recursive manner, such that edges that are not significant at α = .01 are automatically and recursively removed. The pruned models are then optimized by a step-up search process with significance level of .01, such that the edges that are removed in the previous steps are added back, based on modification indices, until BIC no longer increases.

Results

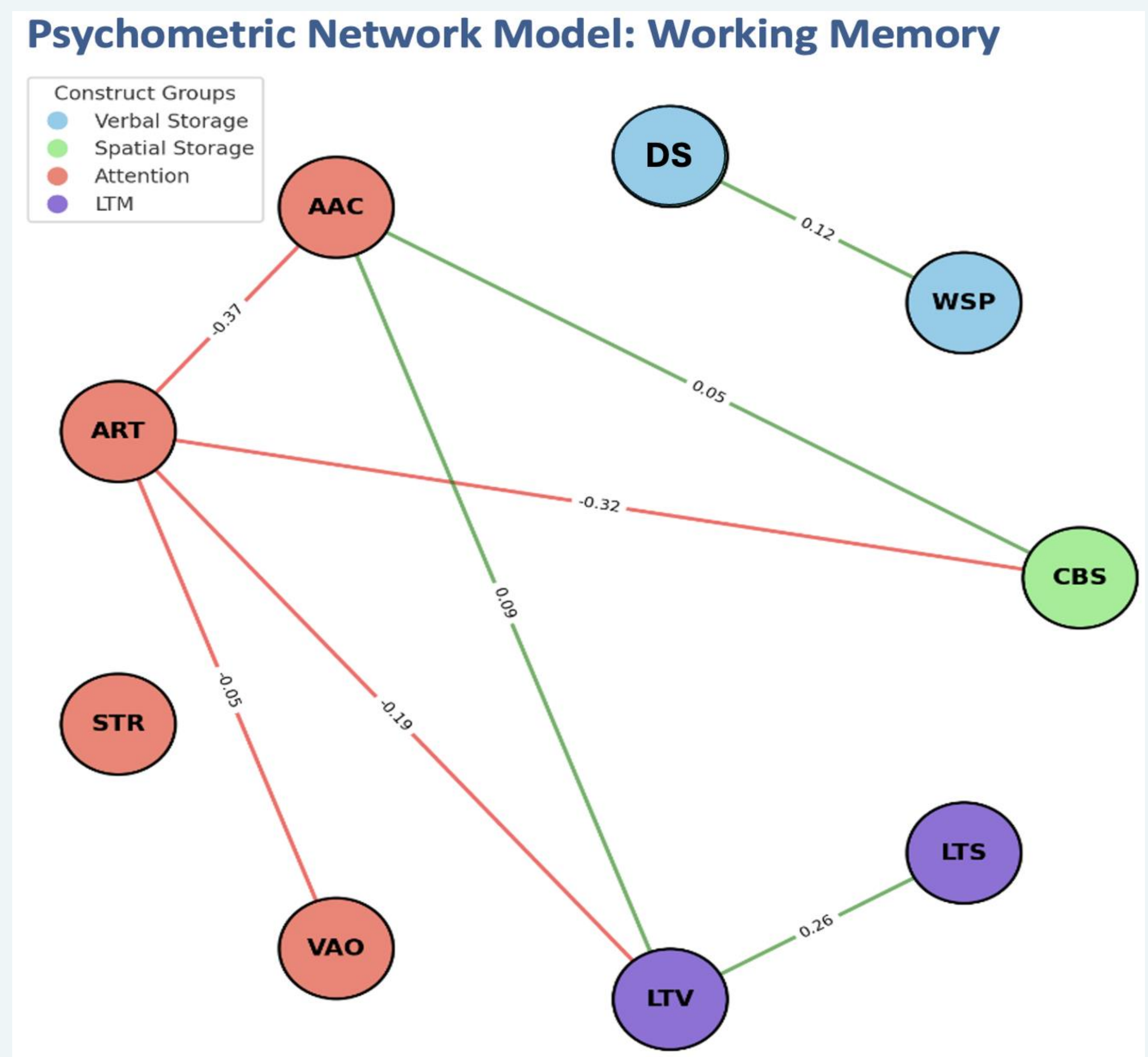
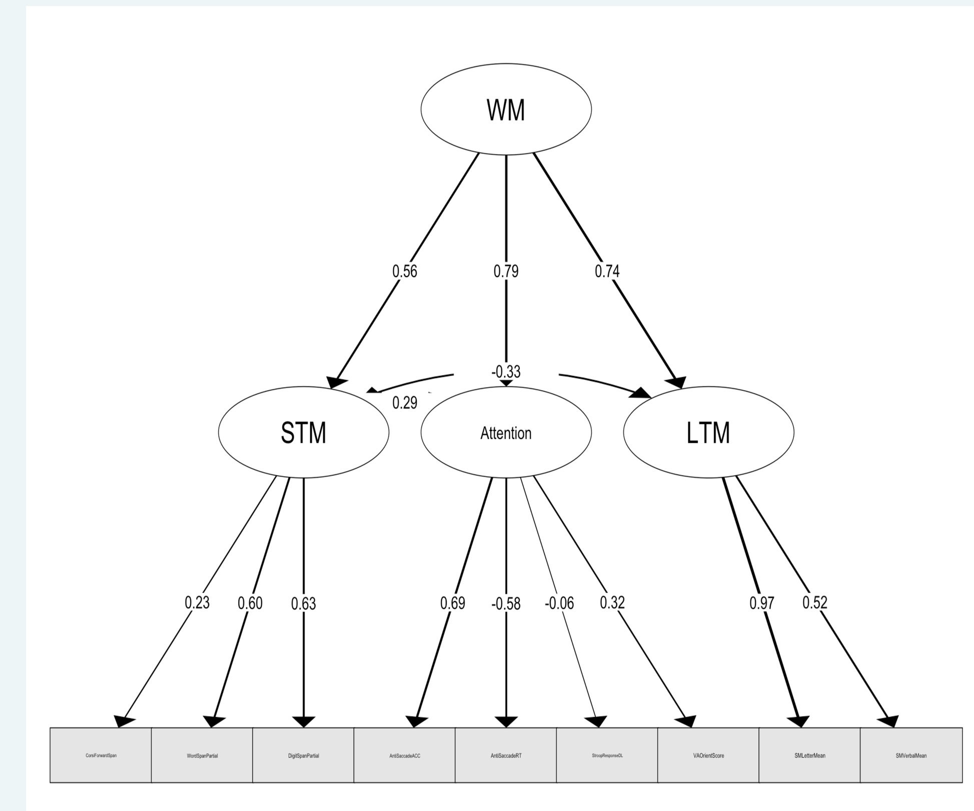


Figure 1: Network Model of Working Memory

Note: Figure note. CBS: Corsi Blocks Forward Span, WSP: Word Span Partial Score, DS: Digit Span Partial Score, AAC: Antisaccade accuracy, ART: Antisaccade RT, STR: Stroop Response DL (ms), VAO: VA Orient Score, LTV: SM Letter Position Mean Score, LTS: SM Verbal Mean Score.
$\chi/df = 3.33$ $p = 0.005$, TLI = 0.93, CFI = 0.95, RMSEA = 0.23, SRMR = 0.04

Results (Continued)



Note: WM = Working Memory, STM= short-term memory, LTM= long-term memory. $\chi/df = 2.10$, $p = <.01$, TLI = 0.63, CFI = 0.78, RMSEA = 0.11, SRMR = 0.10,

Figure 2: Latent Variable Model of Working Memory

Discussion

The purpose of the current study was to examine the structure of WM using network analysis. Per previous research, we included measures of attention, verbal storage, spatial storage, and long-term memory retrieval. The findings from the network analysis show that the model of WM that accounts for the aforementioned components fits well (based on the model fit indices). Importantly, the network model corroborates previous work by showing that most of the attention indices are related to other components of WM in a domain-general manner [5]. For example, the RTs for the Antisaccade are related to both long-term memory retrieval and measures of verbal storage. In addition, the long-term memory retrieval tasks form a cohesive structure as is true of the short-term storage tasks as well. Particularly, the verbal short-term storage tasks show converging validity. In sum, all four theoretically-driven components of WM exist as a cohesive structure in the current network analysis where attention appears to be an especially central component of the model. This is in-line with previous work denoting the central role that attention plays in producing individual differences in WM capacity. Second, the latent variable model of WM corroborates this finding as well. The attention latent variable holds the highest coefficient in the model. However, in contrast, the latent variable model does not show good fit. This supports that the network model may be a more optimal way of representing the true psychometric nature of WM. Overall, the current study provides evidence that network analysis is a viable way of studying the nature of WM and helping to bridge the gap between cognitive models and psychometric models of WM.

References

Scan QR code for references list.

For questions, comments, or to request further information please contact: Dr. Kevin Rosales at kevin.rosales@csusb.edu
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