COGNITIVE SCIENCES AND HUMAN DEVELOPMENT

Evaluating the Psychometric Properties of the Working Memory Questionnaire (WMQ) in Malaysian Tertiary-Level Chess Players

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ABSTRACT

Playing chess has been shown to significantly enhance working memory performance. The original Working Memory Questionnaire (WMQ) is a reliable tool for assessing working memory in both healthy and unhealthy individuals, as validated in the context of France. However, the WMQ has not yet been validated for use with tertiary-level chess players in Malaysia, raising concerns about its reliability and applicability in this context. This study aimed to evaluate the reliability and factor structure of the WMQ among Malaysian tertiary-level chess players. A total of 357 participants completed the 30-item of WMQ and demographics information. Cronbach's Alpha was used to assess the reliability of the scale, while Confirmatory Factor Analysis (CFA) was conducted to examine the validity and factor structure of the WMQ. The results showed a high Cronbach's Alpha of .971, indicating strong internal consistency. Additionally, CFA suggested that all items were well-correlated. To improve model fit, CFA recommended the removal of one redundant item with low factor loadings. Overall, the findings of this study demonstrate that the WMQ is both reliable and valid for evaluating working memory in tertiary-level chess players in Malaysia.

Keywords: working memory, chess players, tertiary education, confirmatory factor analysis

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https://doi.org/10.33736/jcshd.8886.2025
e-ISSN: 2550-1623

Manuscript received: 31 January 2025; Accepted: 20 March 2025; Date of publication: 31 March 2025

1 INTRODUCTION

Working memory is a multi-component system responsible for temporarily storing information and facilitating its use in ongoing cognitive functions (Baddeley & Hitch, 1974), and it is also considered a generic form of working memory (Cowan, 1988). Working memory is an essential component of cognitive functions, playing a crucial role in learning, problem-solving, daily activities, and goal-directed tasks. For instance, Premeti et al. (2024) suggested that children with poor working memory struggle with cognitively demanding tasks, leading to difficulties in learning. The multi-component model proposed by Baddeley et al. (2020) describes working memory as comprising several components: the phonological loop, visuospatial sketchpad, central executive, and episodic buffer. The phonological loop retains verbal and auditory information, such as mentally rehearsing or repeating a phone number. The visuospatial sketchpad allows individuals to visualise and manipulate images, such as picturing a map or a chessboard. The central executive functions as the system's manager, directing attention and coordinating tasks, while the episodic buffer integrates information from various sources, linking sensory information (what we see and hear) with long-term memory. Spencer (2020) further defined working memory as a cognitive system that actively retains and manipulates information to facilitate cognitive operations. Barrouillet and Camos (2020) described it as a structure in which mental representations are constructed, maintained, or modified based on individuals' goals and the current contents of consciousness.

Previous studies have recognised working memory as a key cognitive element in chess (Atashafrouz, 2019; Mikhaylova et al., 2021). In an experimental study, Atashafrouz (2019) examined 40 male high school students, with 20 in the control group and 20 in the experimental group. The findings revealed that participants in the experimental group, who underwent 15 training sessions and practised chess for four months, showed significant improvement in working memory. In competitive tournaments, chess players must choose the best possible moves, often relying on insights from published analyses (Gobet & Charness, 2018). Research has explored chess across various levels of expertise and domains. For example, Ercan (2020) investigated the Turkish Chess Championship and concluded that moderate anxiety levels can positively impact chess performance, reinforcing the idea that chess is an intellectually stimulating game that enhances cognitive functions. Given the importance of cognitive functions for student-athletes, including tertiary-level chess players, it is essential to examine chess and working memory to improve performance strategies. Lastima and Gayoles (2020) further supported this claim, highlighting that chess positively influences several cognitive skills, including auditory memory and working memory. Consequently, working memory is a crucial factor for tertiary-level chess players, enabling them to remain focused and make informed decisions based on experience. Fuentes-García and colleagues (2020) found that stronger chess players adapt more effectively to increased difficulty levels, as evidenced by an experiment in which participants played against a chess engine using a laptop.

Chess has been widely recognised for its application across various domains, offering numerous cognitive benefits at both individual and group levels. A recent study by Mikhaylova et al. (2021b) found that chess training effectively improves intellectual and psycho-emotional skills, accelerating strategic thinking and enhancing competitive cognitive abilities. Moreover, Bolton and Robinson (2017) investigated how anxiety, induced by the threat of shock, affects memory encoding and retrieval. Their study of 78 participants found that visuospatial working memory improved under threat, enhancing the ability to retain and manipulate visual and spatial information, such as shapes or locations. However, the opposite effect was observed for facial memory: being under threat impaired the ability to store and later recall faces, regardless of the retrieval conditions.

Jankovic and Novak (2019) proposed that chess serves as an effective educational tool, enhancing memory, concentration, and other cognitive functions. Similarly, Sosa and Aguilar (2021) highlighted the potential of chess as a powerful educational tool for teaching mathematics and improving visual memory. However, the relationship between cognitive ability and chess remains inconclusive, as some studies suggest no significant difference in visuospatial memory or general intelligence between chess grandmasters and non-chess players (Burgoyne et al., 2016). Given these conflicting findings, further research is needed to explore the effect of chess on cognitive variables and to better understand these discrepancies.

Cibeira et al. (2021) examined the effect of chess training on older adults residing in nursing homes or attending day-care centres. Their results indicated that one-hour chess sessions, held twice a week for twelve weeks, significantly enhanced cognitive functions, including processing speed, attention, executive function, and overall quality of life. Furthermore, Surana (2021) reinforced these findings, noting that chess players tend to outperform non-players in cognitive performance due to the game's various cognitive benefits, such as improved decision-making and memory. Even former world chess champion Garry Kasparov has stated that the ability to mentally visualise chess matches is a common trait among top players (Leskowitz, 2021). Therefore, these findings suggest that experienced chess players can mentally visualise the chessboard and pieces, enabling them to play without needing a physical board or pieces.

The Working Memory Questionnaire (WMQ) (Vallat-Azouvi et al., 2012) is one of the self-reported scales used to measure working memory. The WMQ assesses three dimensions of working memory: short-term storage, attention, and executive control. Higher scores indicate difficulties or weaker working memory performance in individuals (Vallat-Azouvi et al., 2012). The first dimension, short-term storage, is defined as the ability to retain information for a brief period, including memorising numerical sequences, comprehending written text, or performing mental calculations. For instance, recalling a phone number and writing it down. The second dimension, attention, involves processes related to distractibility, mental fatigue, cognitive slowing, and dual-task processing. An example would be maintaining focus during a conversation with multiple people. Finally, executive control encompasses decision-making, planning, and cognitive flexibility. For example, when an individual recognises a mistake in their decision-making process, they may struggle to adjust their strategy accordingly. All three domains are highly correlated, and their combined scores provide an overall assessment of an individual's working memory (Vallat-Azouvi et al., 2012).

The original version of the Working Memory Questionnaire (WMQ) has been consistently used to assess working memory in both healthy and unhealthy individuals within the French context. However, its applicability to chess players in Asian countries, particularly in Malaysia, has yet to be established. This study aimed to validate the factorial structure of the WMQ and assess its reliability among tertiary-level chess players in Malaysia. Investigating the psychometric properties of the WMQ within this population is important for several reasons. First, tertiary-level chess players often exhibit advanced cognitive abilities, particularly in working memory, which is crucial for strategic gameplay. Ensuring that the WMQ accurately measures working memory in this group will help validate its effectiveness as an assessment tool. Second, the findings of this study could inform educational, and training programmes aimed at enhancing working memory, potentially benefiting both academic and chess performance. Overall, a better understanding of the psychometric properties of the WMQ among tertiary-level chess players will contribute to a broader understanding of cognitive and non-cognitive skills in this population.

2 METHOD

2.1 Participants

The population of tertiary-level chess players in Malaysia is estimated to be 4,765, according to the Chess Club of a Malaysian public university. Using purposive sampling, this study recruited 357 tertiary-level chess players from various universities across the country. Recruitment was based on self-reported screening against inclusion and exclusion criteria. The sample size was deemed adequate (Krejcie & Morgan, 1970) and met the minimum requirement for confirmatory factor analysis (CFA), which requires at least 300 participants (MacCallum et al., 1999).

The inclusion criteria specified that participants must be FIDE (Fédération Internationale des Échecs) registered chess players, currently enrolled in a tertiary education institution, and in good mental and physical health. The exclusion criteria included individuals diagnosed with psychological disorders or those who had used prohibited substances listed in the World Anti-Doping Agency's International Standard Prohibited List (Ribeiro & Cascais, 2024). All participants voluntarily took part in the study and provided informed consent. The research was reviewed and approved by the Human Research Ethics Committee (Reference no: 2023-116-01).

2.2 Measures

The Working Memory Questionnaire (WMQ) was developed by Vallat-Azouvi et al. (2012) to assess working memory deficits. The WMQ is a self-administered questionnaire consisting of 30 items rated on a 4-point Likert scale, ranging from 0 (Not at all) to 4 (Extremely). It has three subscales: short-term storage, attention, and executive control.

The short-term storage subscale (items 3, 5, 7, 11, 15, 17, 21, 25, 27, 30) assesses an individual's ability to retain information for a short duration (e.g., "Do you have problems with remembering a sequence of numbers, for example, when you have to note down a telephone number?"). The attention subscale (items 1, 4, 8, 10, 13, 16, 19, 22, 24, 28) evaluates mental slowness, distractibility, mental fatigue, and dual-task processing (e.g., "Do you need to make an effort to concentrate in order to follow a conversation in which you are participating with many other people?"). The executive control subscale (items 2, 6, 9, 12, 14, 18, 20, 23, 26, 29) examines decision-making, planning ahead, and shifting (e.g., "When you are carrying out an activity, if you realise that you are making a mistake, do you find it difficult to change strategy?"). Scores from all three subscales were computed to generate a total working memory score (0 to 120), where higher scores indicate greater working memory difficulties.

The WMQ has demonstrated good internal consistency in both healthy individuals and patients with brain injuries, with Cronbach's alpha values of .89 and .94, respectively (Vallat-Azouvi et al., 2012). Additionally, the WMQ has shown good temporal stability, as confirmed by Guariglia et al. (2019) in a study involving 697 healthy Italian participants aged 18 to 88 years, where the Italian version of the WMQ was found to be both reliable and valid for assessing different aspects of working memory. Furthermore, Vallat-Azouvi et al. (2012) reported that the WMQ exhibits strong concurrent validity with the Cognitive Failure Questionnaire (CFQ) and the Rating Scale of Attention Behaviour (RSAB), demonstrating high correlations with these two measures (Spearman's Rho = .90 and .81, respectively, both $p < .0001$).

2.3 Procedure

An approval letter from the chess tournament organiser, permitting the researcher to collect data from participants, was also obtained. After receiving approval from both the ethics committee and the tournament organiser, the questionnaires were distributed online via a designated social media group targeting the population.

2.4 Analysis

Statistical analyses were conducted using IBM SPSS Statistics version 27 and Analysis of Moment Structures (AMOS) version 28. The participants' demographics (refer to Table 1) were analysed using frequencies and percentages for categorical data, while means and standard deviations were used for continuous data. All variables were checked both statistically and visually for normal distribution. Cronbach's alpha was used to assess the internal consistency reliability of the WMQ, while confirmatory factor analysis (CFA) was performed to examine the construct validity of the WMQ among Malaysian tertiary-level chess players.

3 RESULTS

3.1 Participants' Characteristics

A total of 492 responses were initially collected for this study. After removing incomplete and missing data, 357 valid responses remained for analysis. The demographic information of the participants is presented in Table 1. Participants' ages ranged from 19 to 54 years, with a mean age of 24.18 years (SD = 4.75). Slightly more than half of the participants were female. In terms of ethnicity, the majority were Chinese (63.9%), followed by Malay (26%), Indian (7%), and other ethnicities (3.1%). Regarding chess ratings, only six participants had a FIDE rating between 1000 and 2000, while the remaining 351 participants had ratings between 0 and 999. Notably, two participants held titled status, with one being an International Master (IM) and the other a Women Candidate Master (WCM).

On the WMQ, participants had a mean total score of 62.71 (SD = 25.26), indicating variability in working memory function. The mean scores for the subscales were 21.80 (SD = 8.39) for attention, 20.05 (SD = 8.82) for executive control, and 20.86 (SD = 8.92) for short-term storage, suggesting variability across these components.

Table 1. Demographic information of participants (*n*=357).

Variable	*n*	Percentage (%)	Mean	Standard Deviation
Age			24.18	4.75
Gender				
Female	206	57.7		
Male	151	42.3		
Ethnicity				
Chinese	228	63.9		
Indian	25	7		
Malay	93	26.1		
Others	11	3		
Year of playing chess			3.57	3.43
Rating				
0-999	351	98.3		
1000-2000	6	1.7		
Title				
Titled	2	0.6		
Non titled	355	99.4		
WMQ (0-120)			62.71	25.26
Attention			21.80	8.39
Executive Control			20.05	8.82
Short-term storage			20.86	8.92

Note: Rating is a number that estimates a chess player's skill level based on their performance in games and tournaments. Title is an official designation given to chess players based on their performance and rank.

3.2 Correlation Coefficients Between the WMQ Subscales

Pearson correlation analysis was conducted to examine the relationships between the three WMQ subscales: Attention, Executive Control, and Short-Term Storage. The results revealed that all correlations were statistically significant at $p < .001$, indicating strong positive relationships among the subscales (refer to Table 2). Specifically, Attention and Executive Control exhibited the highest correlation ($r = .910$, $p < .001$), suggesting a close link between these two functions, with better attention skills being associated with stronger abilities in controlling thoughts and actions. Additionally, Attention showed a strong correlation with Short-Term Storage ($r = .898$, $p < .001$), while Executive Control was also highly correlated with Short-Term Storage ($r = .897$, $p < .001$). These findings align with previous research, which suggests that attention plays a crucial role in both executive functioning (controlling thoughts and actions) and short-term storage (temporarily holding information) (Baddeley, 2012; Engle, 2002). The strong correlations indicate that these cognitive components are not entirely distinct but are closely interconnected (Cowan, 2017).

Table 2. Pearson correlations coefficients between the WMQ subscales: attention, executive control and short-term storage (*n* = 357).

	Attention	Executive Control	Short-term storage
Attention	-	-	-
Executive Control	.910**	-	-
Short-term storage	.898**	.897**	-

** *p* < .001 (2 tailed)

3.3 Internal Consistency

The internal consistency of the WMQ was evaluated with Cronbach's α. Table 3 presents the Cronbach's α coefficients for both the full scale (α = .971) and the subscales: Attention (α = .912), Executive control (α = .924) and Short-term storage (α = .971). All values were high, indicating good internal consistency.

Table 3. Internal consistency of the WMQ.

Scale		Cronbach's Alpha	Number of items	Mean	SD
WMQ		.971	30	62.71	25.26
Subscale	Attention	.912	10	21.80	8.39
	Executive Control	.924	10	20.05	8.82
	Short-term storage	.971	10	20.86	8.92

3.4 Construct Validity: CFA for the Initial Hypothesised Model

A confirmatory factor analysis (CFA) was conducted to evaluate the factor structure of the three-dimensional model of the WMQ. This study hypothesised three latent factors: Attention (A), Executive Control (E), and Short-Term Storage (S). The model fit was assessed using multiple fit indices: Chi-Square (χ^2), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardised Root Mean Square Residual (SRMR).

The Chi-Square value for the model was significant, $\chi^2(93) = 1294.905$, $p = .000$, with a CMN/DF ratio of 402, indicating an acceptable fit relative to the degrees of freedom. However, the Goodness of Fit Index (GFI) was .775, suggesting a poor fit between the hypothesised model and the observed data. Similarly, the Comparative Fit Index (CFI) and Normed Fit Index (NFI) were .886 and .844, respectively, both suggesting a poor fit. Additionally, the Root Mean Square Error of Approximation (RMSEA) was .079 with a 90% confidence interval of .074 to .084, and a PCLOSE value of .000, indicating a moderate model fit in terms of approximation (see Table 5).

Given the low model fit, modifications were made to improve the model's performance. Hair et al. (2010) suggested that acceptable factor loadings should be ≥.50, with ideal values above .70. Therefore, items with factor loadings below .70 were considered for removal to improve model validity. Table 4 presents the standardised factor loadings for the three-factor model, demonstrating that all items loaded significantly onto their respective factors ($p < .001$), with values ranging from .0 to .9. Items with factor loadings greater than .70 confirmed that they adequately measured their respective constructs. To achieve a better-fitting model, items A1, A2, A6, E2, S1, and S2, with factor loadings lower than .70, were removed. After the removal of these items, the standardised factor loadings of the final revised model are shown in Table 4.

Next, the modification indices (MI) were evaluated to identify issues and enhance the goodness of fit. Model fit can be improved by either correlating error terms or removing redundant items (Hair et al., 2010). This process was conducted iteratively until an acceptable model fit was achieved, as shown in Figure 1.

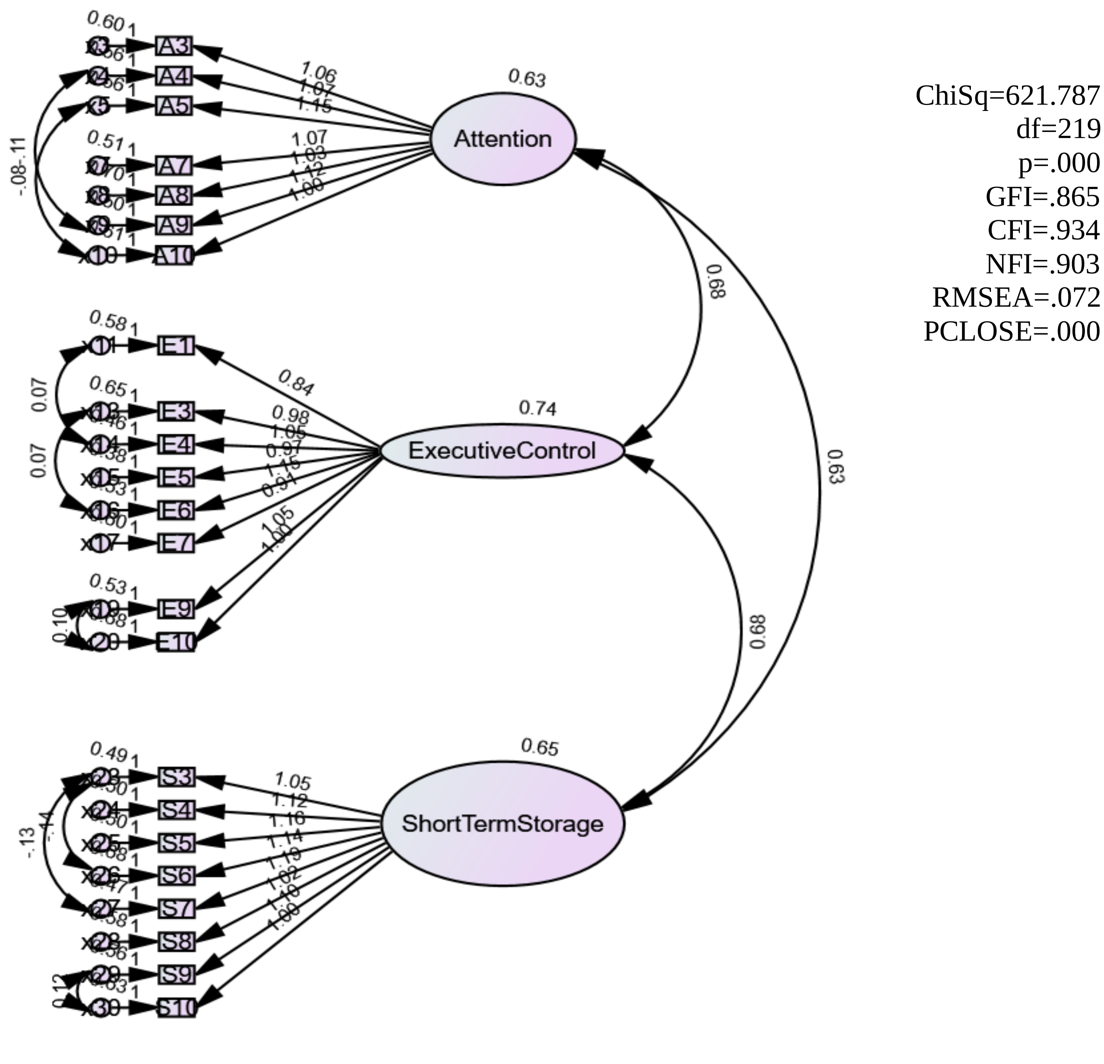

Figure 1. The Modification Indices (MI) of the WMQ.

Table 4. The 30 items of the WMQ and their psychometric properties (*n* = 357).

No.	Item	Mean	Standard Deviation	Item-total correlations	Factor Loadings (initial model)	Factor Loadings (final model)
A1	Do you feel that you tire quickly during the day?	2.44	1.03	.583	.584	Item deleted
A2	Do you need to make an effort to concentrate in order to follow a conversation in which you are participating with many other people?	2.34	1.09	.67	.673	Item deleted
A3	When you are interrupted during an activity by a loud noise (door slam, car horn) do you have difficulty in getting back to the activity?	2.12	1.14	.723	.735	.736
A4	Do nearby conversations disturb you during a conversation with another person?	2.11	1.13	.731	.745	.750
A5	Do you find it difficult to do two (or several) things at the same time such as:- DIY and listening to the radio at the same time?- Cooking and listening to the radio at the same time?	1.85	1.18	.74	.758	.772
A6	Do you feel that fatigue excessively reduces your concentration?	2.49	1.13	.626	.633	.633
A7	Do you find it difficult to carry out an activity in the presence of back-ground noise (traffic, radio or television)?	2.03	1.11	.738	.757	.765
A8	Do you feel embarrassed when you have a conversation with an unfamiliar person?	2.10	1.17	.69	.700	.696
A9	Do you feel that you are very slow to carry out your usual activities?	2.02	1.14	.769	.782	.784
A10	Do you find that you tire quickly during an activity which demands a lot of attention (for example, reading)?	2.31	1.11	.719	.725	.713
E1	Do you find it difficult to carry out a project such as choosing and organising your holidays?	2.13	1.05	.708	.715	.688

No.	Item	Mean	Standard Deviation	Item-total correlations	Factor Loadings (initial model)	Factor Loadings (final model)
E2	When you shop, do you often spend more than the budget you set for yourself? (Aside from the change of currency to the euro!)	2.06	1.15	.684	.696	Item deleted
E3	Do you find it difficult to carry out an activity with chronological steps (cooking, sewing, DIY)?	1.77	1.17	.706	.724	.726
E4	Do you have difficulty in organising your time with regard to appoint-ments and your daily activities?	1.97	1.13	.785	.802	.799
E5	When you are carrying out an activity, if you realise that you are making a mistake, do you find it difficult to change strategy?	2.03	1.04	.776	.801	.804
E6	Do you find it difficult to follow the different steps of a user's guide (putting kit furniture together, installing a new electrical device)?	1.83	1.23	.772	.795	.807
E7	Are you particularly disturbed if an unexpected event interrupts your day or what you are in the process of doing?	2.27	1.10	.709	.720	.712
E8	Do you find that you hesitate for a long time before buying even a common item? (Aside from the change of currency to the euro!)	2.18	1.20	.660	.673	Item deleted
E9	Do you have difficulty in managing your paperwork, sending social security papers, paying bills, etc.?	1.89	1.16	.758	.781	.782
E10	After doing your shopping, are you surprised to find that you have bought many useless items?	1.91	1.20	.702	.725	.723
S1	Do you have problems with remembering sequences of numbers, for example, when you have to note down a telephone number?	2.09	1.12	.678	.686	Item deleted
S2	Do you find it difficult to remember the name of a person who has just been introduced to you?	2.32	1.14	.6222	.646	Item deleted

No.	Item	Mean	Standard Deviation	Item-total correlations	Factor Loadings (initial model)	Factor Loadings (final model)
S3	Do you have difficulty remembering what you have read?	2.22	1.10	.757	.768	.770
S4	Do you need to re-read a sentence several times to understand a simple text?	2.10	1.15	.773	.797	.787
S5	Do you have difficulty understanding what you read?	1.82	1.17	.763	.790	.798
S6	When you pay cash for an item, do you have difficulty in realising if you have been given the correct change? (Aside from the change of currency to the euro!)	1.86	1.24	.699	.721	.745
S7	If a character in a text is designated in different ways (he, him), do you have difficulty in understanding the story?	1.84	1.18	.772	.787	.812
S8	Do you have to look at a written phone number many times before dialling a number that you don't know off by heart?	2.13	1.12	.724	.747	.734
S9	If somebody speaks quickly to you, do you find it difficult to remember what you were told or asked?	2.24	1.16	.760	.778	.764
S10	Do you find it difficult to participate in a conversation with several people at once?	2.25	1.14	.712	.724	.712

Note: WMQ (Vallat-Azouvi et al., 2012) = Working Memory Questionnaire; A= subscale attention; E= subscale Executive control; S= subscale Short-term storage.

3.5 Construct Validity: CFA for the Final Revised Model

After these modifications, the model fit indices suggested an acceptable fit. The Chi-Square value for the model remained significant, $\chi^2(57) = 621.787$, $p = .000$, with a CMN/DF ratio of 2.19, indicating a reasonable fit relative to the degrees of freedom. The Goodness of Fit Index (GFI) was .865, suggesting a better fit compared to the initial analysis, demonstrating improved alignment between the hypothesised model and the observed data. Moreover, the Comparative Fit Index (CFI) and Normed Fit Index (NFI) were .934 and .903, respectively, both exceeding the recommended threshold of .90, suggesting a strong model fit. The Root Mean Square Error of Approximation (RMSEA) was .072 with a 90% confidence interval of .074 to .084, and a PCLOSE value of .000, indicating that the model demonstrated an adequate fit in terms of approximation (see Table 5). Overall, these fit indices support the validity of the three latent factors, confirming their ability to explain the underlying constructs of attention, executive control, and short-term storage.

Table 6 presents the validity analysis conducted to assess the modified model. According to Hair and colleagues (2010), composite reliability (CR) should exceed .70 to establish construct reliability, while the average variance extracted (AVE) should be greater than .50 to confirm convergent validity. The CR values for all three subscales were above .70, indicating adequate internal consistency: Attention: CR = .898, Executive Control: CR = .914, and Short-Term Storage: CR = .919. Similarly, the AVE values exceeded .50 for all constructs, further confirming that the WMQ demonstrates good construct reliability and validity. Overall, the psychometric properties of the WMQ support the robustness of the model, confirming its suitability for assessing working memory components.

Table 7 presents the correlations between items in the final revised model. The results of this study show that all correlation values are below .80, indicating an acceptable level of inter-item relationships without multicollinearity issues. According to Kline (2015), correlations above .85 may indicate redundancy, suggesting that certain items could be measuring the same construct. Similarly, Hair et al. (2019) highlight that correlations exceeding .80 may signal multicollinearity, which could affect the reliability of the model. Since all item correlations in this study remained below this threshold, each item contributes uniquely to its respective subscale, thereby enhancing the overall validity of the measured constructs.

Table 5. Goodness-of-fit indices for the WMQ.

	Chi-Square	Degrees of Freedom	*p*-value	GFI	NFI	CFI	RMSEA	PCLOSE
Initial model	1294.905	402	.000	.775	.844	.886	.079	.000
Revised model	621.787	219	.000	.865	.903	.934	.072	.000

Table 6. Validity analysis.

	Composite Reliability	Average Variance Extracted	Attention	Executive Control	Short Term Storage
Attention	.898	.556	.746		
Executive Control	.914	.572	.996	.756	
Short Term Storage	.919	.587	.981	.982	.766

Table 7. Item correlations within the final revised model.

Item	A3	A4	A5	A7	A8	A9	A10	E1	E3	E4	E5	E6	E7	E9	E10	S3	S4	S5	S6	S7	S8	S9	S10
A3	1.00																						
A4	.61	1.00																					
A5	.53	.58	1.00																				
A7	.60	.62	.62	1.00																			
A8	.53	.51	.50	.55	1.00																		
A9	.51	.50	.58	.56	.58	1.00																	
A10	.49	.55	.49	.55	.48	.60	1.00																
E1	.53	.54	.55	.48	.46	.50	.52	1.00															
E3	.54	.60	.62	.54	.45	.55	.48	.55	1.00														
E4	.54	.56	.60	.56	.53	.65	.57	.60	.55	1.00													
E5	.56	.61	.66	.60	.56	.68	.53	.53	.60	.66	1.00												
E6	.62	.58	.66	.67	.55	.62	.48	.53	.64	.65	.67	1.00											
E7	.56	.60	.55	.63	.52	.50	.55	.55	.45	.57	.57	.55	1.00										
E9	.53	.55	.57	.60	.53	.66	.52	.55	.57	.64	.64	.63	.55	1.00									
E10	.51	.50	.56	.56	.50	.62	.53	.48	.52	.58	.58	.61	.44	.64	1.00								
S3	.63	.56	.61	.54	.52	.55	.60	.58	.52	.59	.57	.54	.59	.60	.52	1.00							
S4	.63	.60	.58	.60	.49	.57	.54	.55	.58	.67	.62	.59	.54	.55	.49	.66	1.00						
S5	.59	.55	.60	.58	.49	.64	.56	.47	.59	.65	.63	.63	.53	.64	.57	.62	.64	1.00					
S6	.51	.50	.56	.55	.53	.58	.44	.44	.53	.65	.56	.69	.47	.62	.55	.46	.55	.62	1.00				
S7	.60	.63	.64	.62	.58	.62	.55	.49	.63	.61	.66	.72	.54	.60	.64	.52	.60	.67	.62	1.00			
S8	.53	.46	.51	.48	.61	.61	.58	.52	.47	.59	.55	.54	.45	.58	.50	.55	.60	.58	.59	.59	1.00		
S9	.56	.57	.53	.57	.53	.62	.68	.57	.52	.64	.58	.55	.55	.60	.51	.59	.64	.59	.53	.58	.60	1.00	
S10	.46	.50	.53	.51	.60	.59	.56	.56	.54	.55	.55	.56	.52	.57	.54	.54	.59	.52	.52	.54	.56	.63	1.00

4 DISCUSSION

This study demonstrates that the Working Memory Questionnaire (WMQ) exhibits strong reliability and validity, particularly after addressing issues related to low model fit and factor loadings. The findings are consistent with Guariglia et al. (2019), who validated the WMQ among 697 healthy Italian participants aged 18 to 88 years, further confirming its utility across diverse populations. Additionally, these results align with the original validation study by Vallat-Azouvi et al. (2012), which established the WMQ as a valid pre-screening instrument for differentiating patients with brain injuries from healthy controls. More specifically, it reflects the impact of central executive dysfunction on working memory in daily life.

The current study further supports that the WMQ is not only reliable but also adaptable, making it a valuable instrument for understanding working memory across different contexts. Unlike the original study conducted in France (Southern Europe), this study was conducted in Malaysia, a Southeast Asian country, thus expanding the applicability of the WMQ to a different cultural and geographical context. Hence, this study fills a research gap and enhances the reliability and validity of the WMQ in new settings.

Moreover, this study confirms good construct reliability and validity for the three-factor structure of the WMQ, justifying the need to maintain its three subscales. It is possibly the first study to apply the WMQ to Malaysian tertiary-level education chess players, a population characterised by high cognitive and physical commitment as student-athletes. The confirmatory factor analysis highlighted several items with low factor loadings, leading to refinements that further aligned the questionnaire with its theoretical framework. After these refinements, the WMQ's precision in assessing working memory was enhanced. Overall, these modifications improved the reliability and validity of the WMQ for assessing working memory among tertiary-level student-athletes.

Beyond its academic contributions, this study also highlights the practical implications of the WMQ for various stakeholders. Sports psychologists can use the WMQ to assess the working memory capacities of student-athletes, allowing them to develop targeted training programmes to optimise their cognitive performance alongside physical training. For student-athletes, balancing academic and athletic demands can be challenging. Therefore, this study emphasises the importance of well-validated assessment tools for measuring working memory, which can inform the design of effective interventions to improve both cognitive and athletic performance.

However, several limitations of this study deserve attention. First, due to the use of purposive sampling, the findings cannot be generalised beyond the defined inclusion criteria. Nonetheless, this study was specifically aimed at examining dual-commitment individuals—student-athletes who balance academic and athletic demands—to address an existing research gap. Second, the cross-sectional nature of this study limits the ability to assess long-term changes in working memory, as working memory can evolve over time, particularly in response to chess training. The study utilised a questionnaire survey to collect data within a single time frame, with its primary objective being to validate the factorial structure of the WMQ. Despite this limitation, the study effectively demonstrates the psychometric properties of the WMQ, supporting its suitability for assessing working memory in tertiary-level chess players in Malaysia. Third, the study did not control for potential confounding variables such as academic stress, prior cognitive training, or sleep, which may influence working memory performance. While these factors can impact cognitive function, the primary focus was to ensure that the WMQ accurately measures working memory within this specific population. Establishing a validated questionnaire is a priority, as future research will benefit from having a reliable tool for further exploration. Acknowledging these limitations allows future studies to incorporate additional factors, thereby strengthening the findings and expanding the scope of research in this area.

Future studies should expand the sample size and improve sampling methods to enhance the generalisability of findings. A larger and more diverse sample would ensure that the results are more representative of the broader population. Additionally, a longitudinal study is recommended to track changes in working memory performance over time. Such a design would offer deeper insights into how chess practice, tournament experiences, and external pressures influence working memory among tertiary-level education chess players. Furthermore, future studies should aim to minimise confounding variables to strengthen the accuracy of findings on working memory performance. Controlling factors such as academic stress, prior cognitive training, and sleep quality would provide a clearer understanding of the mechanisms underlying working memory.

This study employed Cronbach's Alpha to assess reliability and Confirmatory Factor Analysis (CFA) to investigate the factorial structure of the WMQ. The findings confirm that the WMQ demonstrates good reliability and validity for evaluating working memory in tertiary-level education chess players in Malaysia. These results align with the original validation study by Vallat-Azouvi et al. (2012) and the Italian adaptation of the WMQ by Guariglia et al. (2019). Finally, this study provides clear recommendations for addressing limitations and outlines strategies to enhance future research findings. By refining the methodological approach, future studies can further strengthen the reliability, validity, and applicability of the WMQ across different populations and contexts.

ACKNOWLEDGEMENTS

This research received no specific grant from public, commercial, or not-for-profit funding agencies.

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