COGNITIVE SCIENCES AND HUMAN DEVELOPMENT

Does Gender Difference Play a Significant Role in Verbal and Visuospatial Working Memory Performance?

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ABSTRACT

The present study investigates gender differences in working memory performance, both verbal and visuospatial working memory performance. Quasi-experimental research was conducted individually on 32 undergraduates at a public university in Malaysia, using a reading span task and rotation span task. The performance was based on the total number of correct recalled and the total time taken. Results showed a significant gender difference in the verbal and visuospatial working memory performance. The observation was based on the total time taken, in which males performed more rapidly than females in both tasks. In terms of accuracy, female participants recalled better than their male counterparts in the verbal task, which is consistent with numerous past studies. However, no gender difference was identified in the visuospatial task performance, based on the total number of correct recalled. The study also found that male participants did not show an advantage in visuospatial abilities, contradicting findings by past studies.

Keywords: gender differences, verbal working memory, visuospatial working memory, cognitive functions

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1 INTRODUCTION

Working memory was introduced over 50 years ago and has fascinated scholars since its inception from the most prominent model proposed by Baddeley and Hitch during 1974 (Baddeley, 1992). According to Baddeley (2012), the term working memory was coined from the earlier concept of short-term memory found in the modal model of Atkinson and Shiffrin (1968). To distinguish these two terms, which were explained to be theoretical different, Baddeley (2012) declared that working memory involved a combination of storage and manipulation processes. In contrast, short-term memory was simply referred to as the temporary storage of information.

Over recent years, gender differences and similarities in cognitive abilities became a popular topic of significant interest, and many new findings were gradually contributed to the field. Large numbers of research have been conducted to examine an individual's cognitive development and performance. Past research suggested that working memory plays an essential role in cognitive function, such as general intelligence (Conway, Kane, & Engle, 2003), reading comprehension (Daneman & Carpenter, 1980) and reading ability (Pham & Hasson, 2014), writing ability (Adams, Simmons, & Willis, 2015), and mathematics abilities (Raghubar, Barnes, & Hecht, 2010). However, there is still a lack of studies to examine the effect of gender on working memory performance. Recent studies were regarded as underpowered as there was insufficient evidence to provide the knowledge of gender as a critical factor in predicting one's cognitive functions (Hill, Laird, & Robinson, 2014).

Several studies have investigated the effect of gender on memory performance, either tested on verbal stimuli, visual stimuli, or both. Such comparison between males' and females' cognitive functioning revealed some similarities and differences from numerous studies. Females outperformed males on the tasks related to verbal stimuli, such as verbal fluency, verbal memory, and verbal learning (Torres et al., 2006). Meanwhile, men usually showed an advantage in visuospatial ability, such as mathematics, problem-solving, and visual memory (Torres et al., 2006; Upadhayay & Guragain, 2014).

In 1999, Loring-Meier and Halpern carried out four visuospatial tasks to access four different cognitive components of visuospatial working memory, including image generation, maintenance, scanning, and transitions. Their findings revealed that male participants performed better than their female counterparts at all levels of complexity of these tasks. The finding was further supported by research by Lejbak, Crossley, and Vrbancic (2011) using the "n-back task", suggesting that men outperformed women on the spatial tasks. In Lejbak's study, they implemented three versions of n-back tasks in testing participants' working memory. The verbal task consists of different letters presented in the centre of the screen; the spatial task consists of a black circle located in various locations, whereas the object version consists of series of object images (Lejbak, Crossley, & Vrbancic, 2011). The participants were then required to decide the stimulus they observed "2-back" when each new stimulus was presented on the screen. The total number of correct answers and reaction time were then recorded for analysis.

Gabriel and Sridevi (2016) had worked on research in India to identify the influence of gender factors on memory performance and perceptual abilities among young college students. All the testing tasks were verbally based. As a result, women excelled in all the verbal tasks that had been assigned. While men were typically outperformed women on visuospatial tasks, women were found to have an advantage when related to a verbally labelled task (Munnelly, 2016). Furthermore, a study was done in 16 states across the United States to present a meta-analysis of gender differences in verbal performance assessment. As hypothesised, verbal performance particularly involved writing performance favoured significantly to females than males, indicating that women were more proficient than men in terms of verbal abilities, including memory (Peterson, 2018).

However, not every study revealed significant gender differences in terms of working memory measures. A study in Norway reported no gender difference in visuospatial working memory. Their findings went against the accepted viewpoint that male participants showed an advantage in visuospatial abilities (Amundsen, Garmannslund, & Stokke, 2014). Similar research was conducted by Robert and Savoie (2006), which attempted to identify gender differences in working memory to reflect on the separate operations of either phonological or visuospatial constructs under the central executive's monitoring. A total of 100 participants were exposed to series of working memory tasks, including four verbal and four visuospatial working memory tasks. The finding was concluded that people own highly similar working memory resources. In other words, there was no gender difference concerning working memory performance (Robert & Savoie, 2006).

With all the varying findings documented in past studies conducted primarily on Western countries, further exploration is needed to investigate the effect of gender in both verbal and visuospatial working memory performance, especially in Asian countries. In addition, it is essential to note that cognitive features were not only correlated with brain structures. The other factors such as environment, education and age might also contribute to one's working memory performance. For instance, Lejbak, Crossley, and Vrbancic (2011) 's study involved a significant age gap in female participants, ranging from 17 to 28 years old compared to male participants aged 17 to 21 years old. This age difference between male and female participants may create bias in the findings since age appeared to have modulatory impacts on working memory (Chai, Hamid, & Abdullah, 2018).

Furthermore, it is crucial to choose suitable and applicable tasks to measure one's working memory. Since the term of working memory was evolved from the earlier notion of short-term memory, it made a considerable confusion of both concepts and terms to be used in recent literature (Cowan, 2008; Aben, Stapert, & Blokland, 2012; Tasnimi, 2017). As a result, the simple span task used to assess short-term memory and the complex span task used to measure working memory were often used interchangeably. Thus, the present study would apply the complex span tasks that required both memorising and processing functions at the same time to identify verbal and visuospatial working memory performance between gender.

The discussion above raised the following research questions:

1. Is there any significant gender difference in verbal working memory performance based on the total number of correct recalled?

2. Is there any significant gender difference in verbal working memory performance based on the total time taken?

3. Is there any significant gender difference in visuospatial working memory performance based on the total number of correct recalled?

4. Is there any significant gender difference in visuospatial working memory performance based on the total time taken?

Based on the findings of previous literature, the present study aimed to investigate the effects of gender in both verbal and visuospatial working memory performance based on the total number of correct recalled (accuracy) and the total time taken. Therefore, this study provides a chance for the students to access their verbal and visuospatial working memory. Self-awareness of one's cognitive abilities may provide insight into individuals' future education choices and career choices. For instance, a higher functioning of visuospatial working memory was critically important in the careers such as architects, pilots, designers, and more (Loring-Meier & Halpern, 1999). In addition, the findings also help to increase the awareness of educators on their teaching methods. It provides a reference for lecturers to prepare the lectures to benefit all students, regardless of male or female students. Demographic factors such as age would be considered to eliminate the gap existing in past studies. The present study would focus on undergraduate students in Universiti Malaysia Sarawak (UNIMAS) between 21 to 24 years old. Moreover, the reading and rotation span tasks would be adopted to measure one's working memory performance.

2 MATERIALS AND METHODS

The present study employed a quasi-experiment with a 2 (male and female) x 2 (verbal and visuospatial working memory tasks) mixed experimental design. A total of thirty-two undergraduates from Universiti Malaysia Sarawak (UNIMAS) with gender-specific were recruited to participate in this study via purposive sampling method. The participants were selected based on gender and age, ranging between 19 to 25 years old. Since the study was conducted during Movement Control Order (MCO) period, the experimental tasks had been prepared using PowerPoint and conducted with participants through online platforms, such as Google Meet, Messenger, and WhatsApp, depending on the availability of the participants.

The instrument was divided into three sections which consist of: (A) Demographic Information, (B) Verbal Working Memory Task, and (C) Visuospatial Working Memory Task.

Reading Span Task was used to assess the participant's verbal working memory performance and was initially developed by Daneman and Carpenter in 1980. The task was constructed with 60 unrelated sentences, with each sentence had 13 to 16 words in length and ended up with a different

word for every sentence (Daneman & Carpenter, 1980). The Reading Span Task was appropriate to be used in measuring verbal working memory performance as it fulfilled the conceptual requirements of both processing and storage of working memory functioning; with the participants required to read aloud the sentences presented visually (the processing requirement) while trying to remember last words of every sentence for later recall (the storage requirement).

The second task was known as Rotation Span Task, developed by Shah and Miyake (1996) to measure visuospatial working memory performance (Robert & Savoie, 2006). The task included five capital letters (F, J, L, P, and R) with seven different orientations (45˚, 90˚, 135˚, 225˚, 270˚, 315˚, excluding upright position, 180˚). The rotation span task also involved both processing and storage processes concurrently, with the participants required to decide whether the letter was "normal" or "mirror-imaged" (the processing requirement) while remembering the orientation of the letter (the storage requirement) that appeared on the screen.

The reading span task was arranged into different sentences in the actual study, starting with two to six sentences. Each series was tested with one trial. The sentences were presented one at a time; each ended up with a different word. While memorising the last word of sentences, the participants had to read aloud the sentence that appeared on the screen. At the end of every series, the participants were given time to recall the last words of sentences in correct serial order. There was no time limit for the participants. However, they were informed to respond as quickly as possible since the time is taken throughout the whole experiment would be measured and recorded by the experimenter. The scoring was then analysed after the experiment.

Following the rotation span task, the letters with different orientations were also divided into different series, which made up from series of two letters until five letters. The examples were also presented one at a time, with 70 combinations (letters × orientations × normal / mirror-imaged) that might be appeared on the screen. The participants had to decide as quickly as possible whether the letter shown was typical or mirror-imaged while memorising its orientations. Same procedures as reading span task, there was no time limit for them during recall session after every series. The scoring and the total time taken were then recorded and analysed by the experimenter.

3 RESULTS

There was a total of 32 undergraduates from UNIMAS participated in this study. Since the study is gender-related, there was an equal distribution between male and female participants. Table 1 shows the demographic analysis of participants in the study, including participants' gender and age. The age of participants ranged from 21 to 24 years old, with most participants were 23 years old. Due to ethical considerations, they all had signed informed consent and agreed to their participation before the experimental start-up.

Table 1. Demographic characteristics of participants

Characteristics		Frequency (n)	Percentage (%)
Gender			
	Male	16	50.0%
	Female	16	50.0%
Age			
	21	1	3.1%
	22	3	9.4%
	23	21	65.6%
	24	7	21.9%

An independent sample t-test was conducted to analyse the collected data to answer the research hypotheses of this study. This statistical test was appropriate to identify the differences in both verbal and visuospatial working memory performances between males and females in terms of the total number of correct recalled and the total time taken.

Table 2. Independent sample t-test results between gender in verbal working memory performance based on the total number of correct recalled

Gender	***n***	**M**	**SD**	***t* (30)**	***p***
Male	16	11.63	3.46	-3.253	0.003
Female	16	15.44	3.16		

The results of the first research question showed a significant difference between gender in verbal working memory performance based on the total time taken, t (30) = -3.253, p = 0.003. According to Table 2, it demonstrated that females were recalled better and scored an average of 15 words correctly (M = 15.44, SD = 3.16) when compared to male (M = 11.63, SD = 3.46).

Table 3. Independent sample t-test results between gender in verbal working memory performance based on the total time taken (in seconds)

Gender	***n***	**M**	**SD**	***t* (30)**	***p***
Male	16	308.89	64.81	-2.309	0.028
Female	16	368.77	80.99		

For the second research question, the results showed that there was a significant difference between gender in verbal working memory performance based on the total time taken, t (30) = -2.309, p = 0.028 As referred to Table 3, it indicated that males responded quicker (M = 308.89, SD = 64.81) than females (M = 368.77, SD = 80.99).

Table 4. Independent sample t-test results between gender in visuospatial working memory performance based on the total number of correct recalled

Gender	***n***	**M**	**SD**	***t* (30)**	***p***
Male	16	10.06	2.41	0.481	0.634
Female	16	9.56	3.39		

For the third research question, the results showed that the number of correct recalled was not significantly higher for males than females, $t(30) = 0.481$, $p = 0.634$, suggesting that there was no significant difference between gender in visuospatial working memory performance based on the total number of correct recalled. Although the difference was not statistically significant, it can be observed that males' mean scores (M = 10.06, SD = 2.41) was slightly higher than females (M = 9.56, SD = 3.39).

Table 5. Independent sample t-test results between gender in visuospatial working memory performance based on the total time taken (in seconds)

Gender	*n*	M	SD	*t* (30)	*p*
Male	16	237.66	71.68	-2.320	0.027
Female	16	300.14	80.37		

For the fourth research question, the result indicated a significant difference between gender in visuospatial working memory performance based on the total time taken, $t(30) = -2.320$, $p = 0.027$. According to Table 5, females were seemed to spend more time (M = 300.14, SD = 80.37) when compared to males (M = 237.66, SD = 71.68).

4 DISCUSSION

Concerning the working memory performances in people, the present study had sufficient power to identify gender differences in working memory abilities. Indeed, females showed an advantage in the verbal working memory task. Previous studies revealed that females were outperformed males on the tasks related to verbal-related stimuli, with their high accuracy in overall verbal recall (Torres et al., 2006; Baer, Trumpeter, & Weathington, 2006). One justifiable explanation for this finding was gender differences and strategies used in information organisations (Loprinzi & Frith, 2018). Females were preferred to use semantic clustering when encoding information, such as during learning and memorising. According to Manning and Kahana (2012), semantic clustering tends to recall semantically related words successively. Since semantic clustering was claimed to correlate with recall performance (Loprinzi & Frith, 2018), this may explain why females could remember more words than males.

While females were superior in verbal working memory tasks, males usually showed an advantage on visuospatial ability, such as mathematical stimuli, problem-solving, and memory (Torres et al., 2006; Upadhayay & Guragain, 2014). However, the analysis showed no gender difference in visuospatial working memory performance based on the total number of correct recalled, indicating that males were not showing higher accuracy in the related task. The present finding was consistent with a study done by Loring-Meier and Halpern (1999) which demonstrated that males were performed faster than females, yet not significantly in terms of accuracy in their designed visuospatial working memory tasks. Loring-Meier and Halpern (1999) assessed different components of visuospatial working memory, including image generation, maintenance, scanning, and transition. As a result, males performed more rapidly than females but did not differ in terms of accuracy.

For working memory performance based on the total time taken, males were found to perform faster than females in both verbal and visuospatial working memory tasks that had been assigned. In the verbal working memory task, females spent an average of 368.77 seconds which was significantly longer than males, who spent 308.89 seconds on average. In a similar condition to the visuospatial working memory task, females spent an average of 300.14 seconds in completing the task. In contrast, males spent an average of 237.66 seconds. These findings can be related to the fact that women were more likely to display low self-confidence, suggesting that the influence to compare with other's ability levels may be one of the reasons that contributed to such gender differences (Lenney, Gold, & Browning, 1983). Females were more uncertain about their answers during recall sessions, and this situation rarely occurred among male participants, who were usually reported as being high confident. Moreover, a significant gender gap in self-esteem levels across all nations reported by Bleidorn et al. (2016) further explained this situation, with males consistently having higher levels of self-esteem than females.

As implications, the present study if gender is a critical factor in predicting one's cognitive functions. Like previous studies, the present study supported the hypothesis that gender differences existed in verbal working memory performance, with females outperformed males on verbal abilities. Since all the participants were undergraduate students, the results of this study enable the educators to understand cognitive differences between both genders. On the other hand, past studies proposed that males usually showed an advantage in visuospatial abilities. However, such a pattern was not observed in the present study. This result had broken the myth that males were proficient in visual and spatial items and performed much better than females in mathematics and science. Thus, it provides insight for students, especially females, on their future education and career choices. For instance, females could actively enrol in STEM fields even though the fields were perceived as male domains with a high demand for visuospatial abilities.

Another important finding of the present study indicated that males performed more rapidly than females in both working memory tasks. Although the contributing factor had not been identified, it does not neglect the fact that self-confidence and self-esteem could affect of overall performance. Females were more likely to display low self-confidence and self-esteem, especially during adolescence, as their body shape changed. Thus, future researchers must consider such contributing factors and make some effort to minimise the relative effects.

Throughout the study, some limitations were highlighted by the researcher. Firstly, the study's sample size was considered small as it only included 32 research participants, with 16 males and females, respectively. With Malaysia's Movement Control Order (MCO) initiative to cope with the COVID-19 outbreak, it was difficult to approach the potential participants since all the learning activities were conducted via online platforms at the students' respective hometowns. Therefore, it is recommended that future researchers include a larger sample size for more than 30 participants, the minimum normal distribution of statistics to obtain higher statistical power for their study. The second limitation in this study is the virtual data collection process. The researcher had to take an alternative to experiment with research participants via online platforms due to the restrictions of this pandemic. Therefore, it is suggested for future studies to involve a physical laboratory experiment that places the experimenter and participant within a specific room to best control those external factors. Another limitation highlighted in the present study is the lack of similar studies

conducted in the Asian context since most of the previous similar research had been done in Western countries. Thus, future researchers are recommended to explore this area further and adopt various working memory tasks to generate a comprehensive study with higher validity, reliability, and accuracy under the Malaysian context.

5 CONCLUSION

The present study has successfully identified gender differences in verbal and visuospatial working memory performance based on the total time taken. It is hoped that the finding of this study will benefit educators to understand different cognitive patterns among students. In addition, the finding of this study could help educators to strategise their teaching and learning methods. Both verbal and visual elements can be integrated into learning materials to accommodate gender differences in learning. This study also shed some light on the students about their working memory performance. Understanding their operational working memory capacity can apply the appropriate method to deal with cognitive activities. Overall, this small-scale study has contributed to the body of knowledge in working memory research, especially for Malaysian undergraduate students.

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