International journal of child development and mental health
ISSN: 2286 - 7481; E-ISSN: 2586-887X
Vol. 11 No. 1 January – June 2023 (30-36)

The role of inattention and poor working memory on mathematical performance among children in elementary school: A mediation analysis

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How to Cite: Lin C. H., Hung P. H.(2023). The role of inattention and poor working memory on mathematical performance among children in elementary school: A mediation analysis .*International Journal of Child Development and Mental Health, 11*(1), 30-36.

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Article Info:
Received: 13 February 2023
1st Revision: 4 April 2023
Accepted: 27 May 2023

Keywords:
ADHD symptoms,
Mathematical performance,
SNAP-IV, Working memory.

Abstract

Poor mathematical performance is a major issue for children with ADHD. The aim of this study is to assess the impact of attention deficit and hyperactivity in relation to mathematical performance. We probed (1) The relationship among the tendency of attention deficit, hyperactivity symptoms, working memory, and mathematical performance. (2) The mediated model of these variables. Seventy-eight students from three primary schools in Tainan, and Kaohsiung areas were recruited. Teachers filled in SNAP-IV questionnaires according to their observations of inattention, hyperactivity/impulsivity in school. The students received computerized working memory batteries and standardized mathematical tests. Inattention and hyperactivity are both related to poor mathematical performance. Inattention is negatively related to working memory and mathematical performance. Working memory plays a mediated role between inattention and mathematical performance. Poor working memory could be a mediator between inattention which is a core of ADHD tendency and poor mathematical scores. Mathematical performance in children with ADHD might be improved by improving working memory.

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by impaired attention, excessive activities and impulsive behavior in children. Children with ADHD have lower academic performance from elementary school to university (Frazier, Youngstrom, Glutting, & Watkins, 2007). According to the study conducted by Capano, Minden, Chen, Schachar, and Ickowicz (2008), approximately 18% of schoolchildren with ADHD experience difficulties with math learning (Capano et al., 2008). There are many empirical studies that indicate that ADHD children do not perform well academically. In a study of 125 ADHD children over 8 year old, it was found that hyperactivity and inattention, combined with ADHD, resulted in lower mathematics performance than the general population. When it comes to math achievement, the ADHD inattentive subtype is even more difficult than other types (i.e. hyperactivity or combined) (Hechtman et al., 2004; Lindsay, Tomazic, Levine, & Accardo, 1999; Marshall, Hynd, Handwerk, & Hall, 1997; Massetti et al., 2008). The inattentive ADHD children were still lower than

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average children and other ADHD children in reading, spelling and math after controlling for differences in intelligence.

Aside from attention and alertness deficits, ADHD is also affected by other brain functions (Seidman, 2006). Among the most critical is the lack of executive function (Sergeant, Geurts, & Oosterlaan, 2002). Deficiencies in executive functioning include self-regulation and deficits in cognitive abilities such as suppressing irrelevant information, transferring, planning, organizing, using working memory, and problem solving. Inhibitory function may be considered a core deficit in ADHD. Due to the inability to suppress irrelevant information, the working memory of ADHD children is overloaded, resulting in the confusion of working memory function and the difficulty of follow-up planning and organizational behavior (Fuster, 1997). According to Barry et al. (2002), ADHD children did less well at reading, writing, and mathematics than non-ADHD children of the same intelligence level. The reason for this, according to Barry, is that the brain has the ability to plan, organize, maintain appropriate responses, and suppress irrelevant information. As Loring & Meador (1999) suggest, a mental computing capability required for intentional complex behaviors is the loss of executive function (Barry, Lyman, & Klinger, 2002). Considering attention as the foundation of executive functioning, children with ADHD may perform poorly in situations requiring attention and other mental operations. Dong et al. (2021) recently identified the potential role of specific executive function domains as a mediator between ADHD and typical development. However, the role of inattention or hyperactivity remains unclear. Therefore, in this study, the model of Lucangeli and Cabrele (2006) is adopted. This model postulates that working memory is a mediating variable that plays a critical role in the association between ADHD symptoms and poor performance in mathematics. According to this hypothesized mediating relationship, path analysis and mediator analysis (Baron & Kenny, 1986) were performed.

Objectives

This study aimed to examine the correlation between ADHD symptoms and mathematical performance and whether working memory can serve as a mediating factor between ADHD symptoms and mathematical performance.

Methods

Participants

The subjects were elementary school students in grades 2-3. In order to obtain the consent of the school and parents before accepting the test, the research team developed publicity materials and consent forms for the project. In addition, the research team conducted a briefing meeting with the school and parents about the project and test procedures. Due to their considerations, some schools and parents have declined to participate after being contacted and explained. Students are divided into three stratified groups based on their performance in the class: outstanding, average, and poor. One-third of the students in each group were sampled. There are 78 valid samples, including 43 males and 35 females. The data were deidentified before being analyzed.

Measures

In this correlational study, teachers were asked to evaluate the students' attention and hyperactivity problems by using the SNAP-IV (Swanson, Noalan and Pelham rating scale version IV) questionnaire. A computerized working memory test was conducted at the same time. After half a year, a standardized mathematical performance test was administered to the students.

1. SNAP Questionnaire

This study used the Taiwanese version of the Attention Deficit Hyperactivity Questionnaire SNAP-IV (Gau et al., 2009; Gau et al., 2008). The questionnaire includes two versions for parents and teachers, including the attention problem subscale (9 items), and the hyperactivity/impulsivity subscale 34 (9 questions). The internal consistency of Cronbach's alpha of both versions was greater than 0.88, and the test-retest reliability (ICC) was between 0.60 and 0.84.

2. The computerized working memory test

The working memory test used in this study was revised from the test developed by Lee, Hung, Chiu Huang, & Lee (2004). The test has 50 questions and is administered by computer. The test includes four parts: spatial tracking, number comparison, orientation memory and number operation. The subtests had high internal consistency (0.81 to 0.89). The internal consistency of the whole test was 0.93, and the correlation between the sub-tests was moderate to high (0.50 to 0.66). The factor analysis showed that the eigenvalue of the first factor was significantly higher than that of the other factors. This tool has impressive reliability and validity.

3. Computerized adaptive mathematics assessment for 3rd & 4th graders

The mathematics aptitude test used in this institute is taken from the question bank developed and updated by Hung, Hsiao, & Yang (2018). For students in grades 3 and 4, the test content includes four categories: statistics and algebra, quantity and measurement, number and calculation, and graphics and space. Also, the test questions in the question bank are all analyzed by Item Response Theory (IRT), and the relevant parameters of the questions have been established and scaled, and the children's abilities estimated after the test can be compared across grades. The reliability is 0.83.The linearity of the data was tested before it was analyzed. As the assumption is not violated, multiple regressions were used for probing the association between ADHD and mathematical performance. Testing a working memory-mediated process model using path analysis, the Sobel Z test was employed.

Results

The descriptive statistics of the participants' SNAP IV questionnaire, working memory test, and computerized adaptive mathematics assessment scores were shown in table 1.

Table 1: Descriptive statistics for attention, working memory, and mathematical performance of the participants (n=78)

Assessments	Mean	SD
SNAP IV total score	13.85	13.00
Attention problem subscale	7.40	6.48
Hyperactivity/Impulsivity subscale	6.45	7.16
Working memory test	27.42	10.23
Computerized adaptive mathematics assessment scores	13.31	3.76

For building the mediator model, we tested several regression analyses. Multiple regressions indicated that: Working memory = 33.66 – 1.21 inattention + 0.42 hyperactivity. Only attention is predictive in this model, as shown in Table 2. The equation for the association between math achievement and domains of ADHD is:

Math Ability = 9.09 + 0.16 Working Memory – 0.11 Attention Problems + 0.10 Hyperactivity Problems.

Only working memory is predictive in this model, as shown in Table 2.

Table 2: Significant predictors in the path analysis.

Assessments	Predictors	B	β	T	P
Outcome: working memory. $R2 = 0.31$ $F(2, 75) = 16.45$, $P < 0.01$					
	Inattention	-1.21	-0.76	4.67	<0.01
Outcome: Math Ability. $R2 = 0.23$ $F(3,74) = 7.25$, $P < 0.01$	Working memory	0.16	0.43	3.52	0.01

By calculating the standardized regression coefficients of Equation 1 and Equation 4, the path analysis diagram generated is shown in Figure 1.

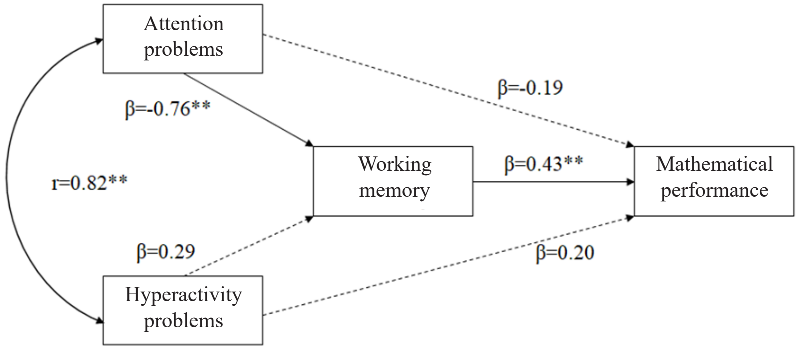

Figure 1. Working memory as a mediation model for attention problems (inattention), hyperactivity, and mathematical ability. The solid line indicates that the pathway is significant, and the dashed line indicates that the pathway is not significant.
***p<0.01.*

Therefore, in the test of the mediation model for the second research purpose, we focused on the mediating effect of working memory in the association between attention problems and poor mathematical ability, and did not include hyperactivity problems in the analysis. The pattern of the test is shown in Figure 2, which shows that there is a significant relationship between attention problems and mathematical ability, $b = -0.15$, $\beta = -0.25$, $t(76) = 2.28$, $p < 0.05$. Simple regression analysis showed that attention was also associated with working memory, $b = -0.83$, $\beta = -0.52$, $t(76) = 5.39$, $p < 0.01$, with working memory The simultaneous prediction of mathematical ability by both memory and attention variables showed that working memory was significantly predictive. In contrast, attention was predictive of mathematical ability becoming insignificant and approaching zero, as shown in Table 3.

Table 3: Spontaneous regression for path analysis.

Assessments	Predictors	B	β	T	P
Outcome: Math Ability					
	Memory	0.17	0.45	3.8	<0.01
	Attention	0-0.01	-0.01	0.1	0.92

Further, the Sobel Z test is used, with the regression coefficient of attention to predict working memory ($b = -0.83$, $SE = 0.15$) and the regression coefficient of working memory to predict mathematical ability ($b = 0.17$, $SE = 0.04$). The mediation effect is $Z = 3.37$ after formula calculation, $p < 0.01$.

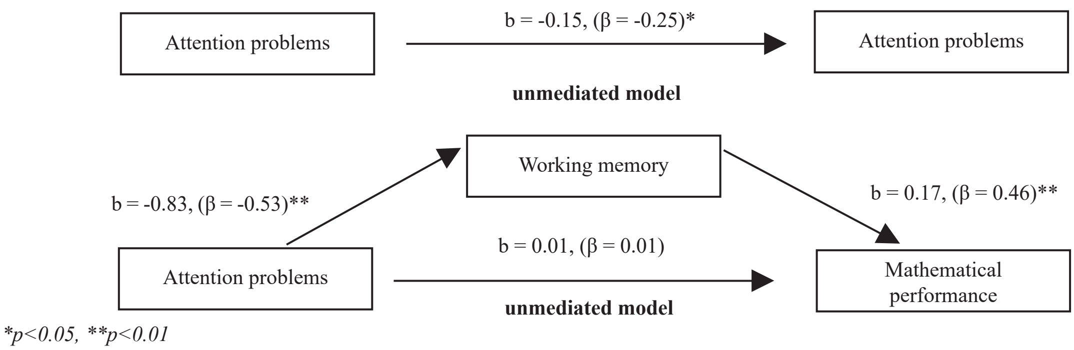

Figure 2. Mediated model analysis of inattention (attention problems)

Discussion

Our study confirmed the model of Lucangeli and Cabrele (2006). We also confirmed the importance of the inattention problem for poor math ability via working memory. In addition, the findings of the present study demonstrate that the findings of Dong (Dong et al., 2021) can be replicated in school children from the community. Our findings test the role of two key components of ADHD: inattention and hyperactivity, and support the role of inattention being more influential than hyperactivity. This information may provide insight into clinical implications.In our study, attention problems had a negative impact on mathematic scores. This is similar to previous studies. Children with ADHD perform poorly in mathematics (Barry et al., 2002). This effect may be due to delayed process speed in calculation and inattention (Zentall, 1993). Meanwhile, it should be noted that the role of hyperactivity could be controversial (Marshall et al., 1997). Our study also found that attention had a negative relation to working memory. Many studies propose that working memory has a prominent role as a primary neurocognitive deficit or endophenotype in extant models of attention-deficit/hyperactivity disorder (ADHD). Lisa found large magnitude working memory deficits in a meta-analysis review. Meta-regression revealed statistically significant moderators of effect size variability across WM tasks. Oberauer (2019) proposed attention is a mechanism that filters out irrelevant stimuli, and removing mechanisms of filtering out irrelevant stimuli, and removing no-longer relevant representations from working memory. Besides, working memory contributes to controlling perceptual attention—by holding templates for targets of perceptual selection—and controlling action—by holding task sets to implement our current goals. Numerous studies have indicated that cognitive impairment is related to academic achievement. We found that children with lower working memory performance had poor math achievement. Caviola et al. (2020) found that symbolic number comparison (SNC) accuracy and spatial WM measures were reliable and mostly specific predictors of math achievement. Verbal short-term and WM and SNC reaction time were predictors of both reading and math achievement. WM fully mediated the relation between approximate number system (ANS) acuity and mathematics achievement (Gimbert, Camos, Gentaz, & Mazens, 2019). The biological mechanism of this finding remains to be elucidated. Although it is well established that the reward pathway and prefrontal function are related to ADHD and working memory (Fallon & Cools, 2014; Funahashi, 2017), little is known about the role of the reward pathway in mathematical ability. It is also worth noting that Volkow et al. In 2004, it was found that dopamine enhanced the saliency of mathematical tasks due to the effect of methylphenidate on the dopamine system. It may also support the use of pharmacological and non-pharmacological interventions for improving ADHD functionality. In clinical implications, children with poor mathematical performance can be assessed with ADHD (such as SNAP) or working memory tests. This may help to understand whether the deficit is related to mathematical learning itself, or due to inattention or poor working memory. Alternatively, behavior training could focus on inattention or working memory. For enhancing the effect of teaching,strategies to shorten the problem-solving time of learners could be considered (Hung, Hwang, Lee, & Su, 2012).To conclude, we confirm previous theories about the role of ADHD tendencies, especially inattention. Children in typical schools who have ADHD tend to perform poorly mathematically due to poor working memory. Interventions could be focused on this problem, such as a modified curriculum to reduce cognitive load. Although the findings of the present study addressed the role of inattention, the influence of hyperactivity on poor working memory and mathematical performance should not be neglected. There are several limitations to the present study: 1. This sample is not randomized, and the sample size is small. 2. It is a cross-sectional study, and the causal model is based on theoretical assumptions. 3. Lack of a specific diagnosis for ADHD or other related mental disorders. 4. As the path analysis is sensitive to the characteristics of the data distribution, future studies, with other methods, such as structure equation modelling, are needed to replicate our proposed model.

Acknowledgement

The authors thank the research assistance provided. Thanks to Dr. Yun Chen for managing the recruitment process. Dr. Shih-Hsien Lin for guidance on data analysis.

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