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Research Paper

Investigating Adolescent Working Memory Through Memory Updating Task: The Impact of Demographic Variables

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ABSTRACT

Adolescence is the age between childhood and adulthood during which individuals experience rapid development, preparing them for more complex social roles and responsibilities. The developmental stage of adolescence is marked by notable changes in social, emotional, cognitive, and physical domains. Working memory is essential for adolescents' cognitive development, influencing their academic performance and overall functioning. The term "working memory" describes the capacity to temporarily store and update data. Working memory is required for complex tasks like language comprehension, problem solving, critical thinking, reasoning, and learning. The memory updating task is an executive functioning test that measures how well adolescents monitor and update information in working memory. Demographic parameters including age, gender, and socioeconomic background can all have an impact on cognitive skills. Understanding these processes is essential for a teacher to provide proper support to kids during this key time. The primary objective of this research is to learn all we can about the effects of age, gender, and socioeconomic status on the working memory capacity of adolescents. The survey study used a purposeful random sampling approach. This study involved 118 adolescents from various schools aged 13 to 17. Quantitative data were collected and analysed. Percentage analysis, t-tests, and correlation analyses were conducted. The t-test, correlation analysis, and percentage analysis were performed. The results of the study indicate that, except from economic level, there are no noticeable distinctions between the gender and domicile status groups. The working memory percentage score of adolescents is 71.9 overall, with the percentage value rising with age and reaching its maximum at 16 underscores the importance of this period of cognitive maturation. The results showed no significant variations in working memory ability based on gender or location. However, considerable variations appeared in terms of economic status and age. Adolescents from higher-income families outperformed their lower-income counterparts in terms of working memory. Similarly, older adolescents (years 15-17) performed better than younger adolescents (ages 13-14), indicating that working memory develops throughout adolescence. There is a minimal association between WM and socioeconomic level, but a significantly positive relationship with age. The study emphasises the importance of tailored treatments and support programmes, particularly

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for economically disadvantaged teenagers, in promoting cognitive development and academic accomplishment.

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Working memory is the ability to temporarily store and manipulate information needed to perform complex cognitive tasks such as reasoning, comprehension, and learning (Baddeley, Hitch & Allen, 2021; Cowan, 2017). WM commonly described as a mental "workbench," this term indicates an individual's capacity to hold task-relevant information in mind during problem-solving and decision-making. It is a theoretical construct central to both cognitive psychology and neuroscience (Martinez, 2000). Research has established that working memory is foundational to academic skills, particularly reading and arithmetic (Jerman et al., 2012). It supports short-term retention of words, meanings, and sequences, contributing significantly to verbal and visuo-spatial abilities (Pisoni & Cleary, 2003). Moreover, it is considered a core predictor of performance in a range of cognitive domains, including reading comprehension (Daneman & Carpenter, 1980; Lustig et al., 2001; El-mir, 2019) and fluid intelligence (Engle et al., 1999; Colom et al., 2004). According to Alloway and Alloway (2010), working memory is a strong predictor of academic achievement across subjects. Miyake and Shah (1999) described working memory as involving mechanisms that actively maintain and regulate information to support complex cognition. The central executive, the episodic buffer, the phonological loop, and the visuospatial sketchpad constitute the four parts of working memory according to Baddeley's model (1992; 2000). Each of these components shows linear developmental growth from childhood to adolescence (Jansen et al., 2019), with cognitive functions such as problem-solving and processing speed improving with age until they plateau in mid-adolescence (Demetriou et al., 2002). Engle and Kane (2004) also emphasized individual differences in working memory capacity (WMC), linking it to attentional control. A critical process within working memory is **memory updating**, which involves monitoring current contents and replacing outdated information with new, relevant input (Miyake et al., 2000). Memory updating tasks, such as the letter memory task, have been widely used to examine this dynamic process (Ecker et al., 2014). Apart from cognitive characteristics, working memory performance is also influenced by social factors like one's gender, age, and socioeconomic status (SES). Research suggests that improvements in prefrontal cortex function during adolescence account for enhanced working memory in older compared to younger adolescents (Gathercole et al., 2004). While gender differences remain inconclusive, some findings suggest males may perform slightly better in spatial working memory tasks, while females may have an edge in verbal working memory (Vuontela et al., 2003). Socioeconomic status is another key determinant; adolescents from higher SES backgrounds often show stronger working memory performance, possibly due to more stimulating environments and better educational opportunities (Noble et al., 2007; Engle et al., 2008; Sturge-Apple et al., 2014). The intention of this study is to use a memory updating task to assess teenagers' working memory ability and investigate how significant social variables affect their performance.

REVIEW OF LITERATURE

Working memory has garnered significant attention from cognitive researchers, especially in the past decade, due to its central role in various facets of human cognition. A key finding from cognitive aging research indicates that working memory capacity declines with age in adults (Byrne, 1996). Working memory, on the other hand, exhibits a consistent developmental gradient in young children and adolescents, growing in size and effectiveness with time. Supporting these findings, Gathercole et al. (2004) explored the structure of working memory from ages 4 to 15. As per the study findings it was discovered that at the age of six, the fundamental elements of working memory - central executive, phonological loop, and visuospatial sketchpad are established. A linear increase in the functional capacity of each component is observed from age 4 to 14, after which performance plateaus between 14 and 15 years. Barrouillet et al. (2009) investigated working memory span development using a time-based resource-sharing model. The results indicated that as people age, their working memory span increases because their memory traces are better reactivated and refreshed. The study also noted that cognitive load has a more pronounced effect on younger children, while older children show greater efficiency in managing memory resources. Nelson Cowan (2016) examined the development of working memory from infancy to school years, emphasizing its importance in cognitive growth and information processing. According to the study, despite a number of complicating variables, working memory develops greater during the school years. A large-scale study by Akhlaghipour and Assari (2020), involving 10,418 children aged 9 and 10, examined the complex interactions of parental education, household income, race, and working memory performance. The findings showed that, especially for White children, stronger working memory was linked to higher family income and parental education. However, among Black children, the positive effects of these socioeconomic factors were significantly weaker, highlighting potential racial disparities in cognitive development. In a different context, Tariq and Noor (2012) explored the impact of working memory on academic achievement among 300 university science students in Punjab, Pakistan. According to the study, there were no substantial gender disparities in academic performance or working memory, suggesting that male and female students functioned equivalent in these cognitive areas.

Need for the Study:

Adolescence represents a crucial period for the development of working memory. Significant changes occur in both the capacity and control processes of WM (Working memory) during this stage (Luna et al., 2004). Studies show that WM continues to develop from childhood into adolescence, typically reaching maturity around the age of 14 to 15 years (Siegel & Ryan, 1989; Cowan, 2016). Variations in working memory are influenced not only by age but also by **demographic factors** such as gender, socioeconomic status (SES), and parental education. Adolescents from higher SES backgrounds tend to demonstrate stronger WM performance, likely due to enriched environments and greater educational support (Finn et al., 2017; Zhao & Maes, 2023). Neuro-imaging studies have also shown that adolescents from higher-income families exhibit greater activation in brain regions associated with WM, such as the prefrontal and parietal cortices (Murtha et al., 2021). Furthermore, WM performance, especially in updating tasks, is influenced by the ability to manage interference and maintain relevant information. These executive processes show variability across individuals and continue to develop into late adolescence (Carriedo et al., 2016). Students with lower WM, particularly those with certain cognitive styles, are more vulnerable to underachievement in academic contexts (Alloway et al., 2010; Banner & Smith, 2010). In light of these aspects, the purpose of this study is to examine how demographic characteristics including gender, age, and socioeconomic status affect cognitive outcomes as well as to assess teenagers' working memory performance using a memory updating task. It is anticipated that the results will influence educational policies and procedures and promote a more comprehensive knowledge of adolescent cognitive development. In this context the present study seeks to address the following **research questions**:

1. What is the level of working memory among adolescent students across different age?
2. Is there a significant difference in working memory updating performance among adolescents based on their age group?
3. Does gender have a significant influence on working memory performance of adolescents?
4. How does the level of working memory differ across adolescent from different localities?
5. What is the relationship between age, socio-economic status, and working memory performance in adolescents?

***Objectives*:**

- To assess the working memory performance of adolescents using the memory updating task.
- To analyze the influence of demographic variables (gender, age, locality and family income) on working memory performance among adolescents.
- To compare working memory updating performance across different demographic groups.

MATERIALS AND METHODS

The current study used a quantitative research methodology to investigate the impact of demographic factors and assess adolescent student's working memory performance using a memory updating task. A total of 118 adolescent students, ranging in age from 13 to 17, were chosen from a variety of educational institutions to reflect a range of backgrounds. Care was taken to ensure demographic diversity in terms of gender, age and locality.

Prior to data collection, necessary permissions were obtained from school authorities. The nature and goal of the study were explained to the participants, and all ethical standards were observed.

TOOL USED FOR DATA COLLECTION:

Working Memory - Letter Memory Updating Task:

Working memory performance was evaluated using the Letter Memory Updating Task developed by Miyake et al. (2012). This task requires participants to continually monitor, update, and revise information held in their working memory. Participants are given a series of spoken letters, one at a time, throughout the exercise. After the sequence is over, they have to remember the final three letters. To ensure continuous updating, participants are required to say aloud the last three letters after each new letter is presented. This encourages continuous updating and displacement of irrelevant information in working memory. In addition to the cognitive task, a demographic data sheet was used to collect participant's age, gender, locality, and family income, allowing for analysis of how these variables relate to working memory performance. Each participant was presented with 20 trials, each consisting of a spoken letter sequence containing 8 to 12 letters. Participants were asked to remember and report the final three letters in the proper order following each sequence. Scoring was done such that one point was awarded only when all three letters were correctly recalled. The maximum possible score was 20. The task was administered individually in a quiet, controlled environment to minimize distractions. Participant responses were recorded and systematically scored for analysis.

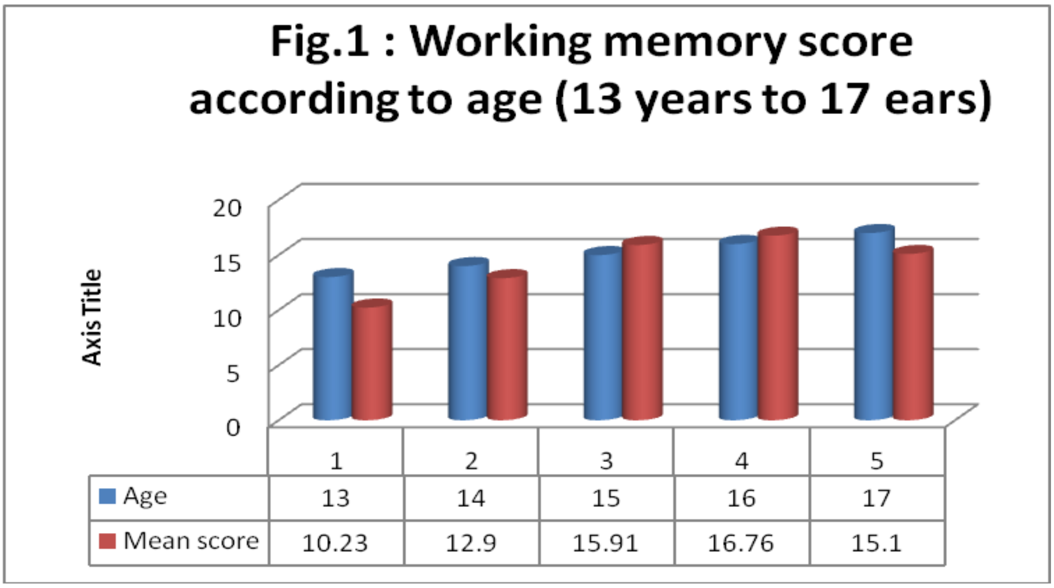
Data Analysis:
Data was analyzed by MS- Excel and SPSS. Percentage analysis, t-test and ANOVA was were used to compare means of two groups and Pearson correlation coefficient was used to correlate the variables.

RESULTS

The performance of adolescents on the memory updating task was analyzed with respect to different age groups. The maximum score possible was 20. The result, indicate a clear developmental trend in working memory performance with age. Participants aged 13 years obtained a mean score of 10.23 (51.5%) suggesting relatively lower working memory updating ability at this early adolescent stage. At 14 years of age there was a noticeable improvement with a mean score of 12.90 (64.5%). A significant increase was observed at 15 years with the mean score 15.91 (79.55 %) and peaked at 16 years with the mean score is 16.76 (83.8 %), indicating that working memory updating skills strengthen considerably during mid –adolescence. However, a slight decline was noted at 17 years with the mean score is 15.10 (75.5%), suggesting possible stabilization or minor fluctuations in working memory performance as adolescents approach in late adolescents. It is also found that the overall percentage score of adolescents on memory updating task is 70.9. The findings suggest that working memory capacity improves with age during adolescence.

Table -1 Working memory Performance of adolescents according to their age

Age	**No. of students**	**Mean score**	**percentage**
13	26	10.23	51.15
14	13	12.9	64.5
15	35	15.91	79.55
16	25	16.76	83.8
17	19	15.1	75.5
	118	14.18	70.9



The findings suggest that working memory capacity improves with age during adolescence, aligning with cognitive development theories (Best & Miller, 2010).

Table-2: Descriptive analysis of Working memory score of total sample.

Mean	14.35043
Standard Error	0.40468
Median	15
Mode	14
Standard Deviation	4.377285
Sample Variance	19.16062
Kurtosis	-0.16623
Skewness	-0.75633
Range	18
Minimum	2
Maximum	20
Sum	1679
Count	118

From, above table.2, It is found that the average working memory score of total sample is 14.35, with a moderate spread (SD= 4.37). The working memory Letter updating task was conducted with a maximum score of 20. The mean score obtained by the participants was 14.35 indicating moderately high level of performance among adolescent. The median score15 and the mode score of 14 further support that most students performed mid to high range, while the distribution is slightly negatively skewed (- 0.756), meaning more scores are clustered toward the higher end. Kurtosis is close to normal (slightly platykurtic), indicating no extreme peaks or tails. The range is from 2 to 20, suggesting wide variability among students working memory performance.

DIFFERENCE BETWEEN THE GROUPS AS PER THEIR GENDER

Table. 3 – Differences in Working Memory Performance across Demographic Groups

Variable	**Group**	**N**	**Mean**	**Std. Deviation**	**t- value**	**p-value**
Gender	Male	62	14.21	4.35	0.45	0.65
	Female	56	14.57	4.58		
Locality	Rural	83	14.18	4.61	0.75	0.45
	Urban	35	14.85	4.02		
Economic status (Annual Income)	≤ ₹ 2 lakhs	72	13.71	4.76	2.09	0.03*
	> ₹ 2 lakhs	46	15.43	3.69		
Age group	13-14 years	39	11.12	4.72	6.5	0.00*
	15-17 years	79	15.98	3.28		

<u>Note:</u>

i) $p < 0.05$, statistically significant difference in working memory performance based on economic status.

ii) $p < 0.001$, statistically significant difference in working memory performance based on age group.

The working memory scores of boys and girls were compared using an independent sample t-test. The average score for both boys and girls indicated that girls performed on average a little better. The findings showed that there was no statistically significant difference in working memory capacity between the adolescent girls and adolescent boys, as evidenced by the p-value of 0.65, which was much higher than the typical cutoff level of 0.05. These results imply that adolescents' working memory ability, as assessed by the memory updating task, is not influenced by their gender.

When we compare the working memory performance between Rural and Urban area adolescent students, The Rural group (N=83, Mean=14.18) and the Urban group (N= 35, M=14.85) showed a slight difference in mean scores on the Memory Updating task. However, there was no statistically significant difference between adolescent students in rural areas and those in urban areas (p = 0.45, which is not less than 0.05). The result suggests that adolescent working memory does not significantly vary according to their locality.

We used an independent sample t-test to see if adolescent students' working memory performance was influenced by their socioeconomic status. Group 1 consisted of student from families with an annual income below or equal to Rupees 2 lakhs (N=72, Mean = 13.70), while group 2 consisted of students from families with an Annual income above Rupees 2 lakhs (N=46, Mean= 15.43). The study findings revealed that there is a considerable difference between the two groups of adolescent students working memory capacity based on their economic situation. (t –value =2.09 and p- 0.03 which is less than 0.05 and it is significant). Students from families with higher income demonstrated significantly better performance on the Memory updating task compared to their peers from lower- income families.

We additionally employed t-tests to compare the effectiveness of working memory between two age groups. Group 1 comprised of adolescent pupils aged 13-14 years (N=39, mean = 11.12), while group 2 consisted of those aged 15-17 years (N=79, mean = 15.98). The results indicated a significant difference between the two age groups (t = 6.5, p = 0.003). Adolescents aged 15-17 years demonstrated much better working memory ability than their younger counterparts aged 13-14 years. This implies that working memory skills develop with age during adolescence, as older adolescents excelled younger ones on the memory updating task.

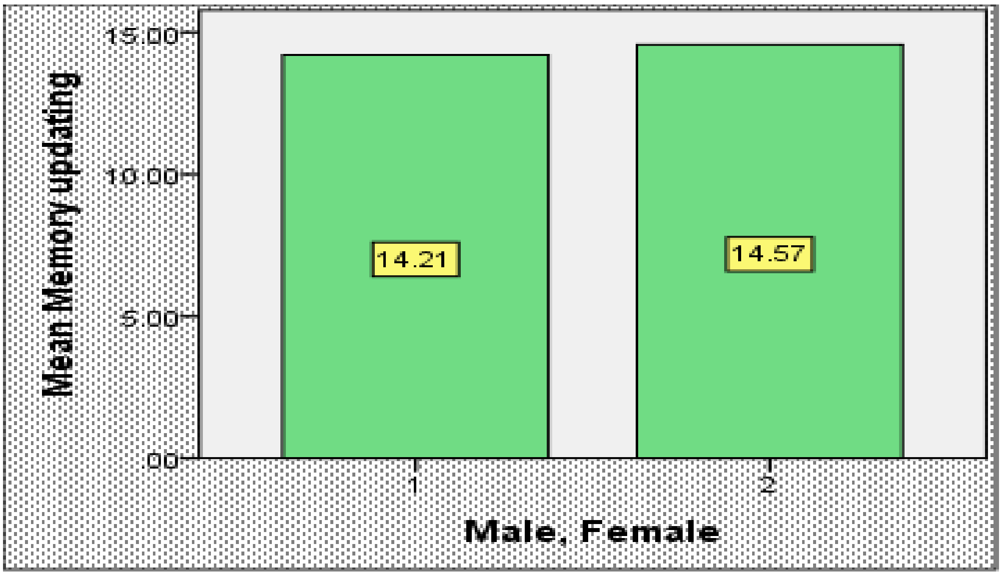


Figure 2: Comparison of Working memory as per the gender (1- Male; 2- Female)

Table 4 : ANOVA (Working memory in age groups)
Working Memory

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	616.493	1	616.493	42.282	.000
Within Groups	1691.346	116	14.581		
Total	2307.839	117			

A one-way ANOVA was conducted to examine the effect of age group on working memory performance among adolescents. From the table.4, The result revealed a statistically significant difference in working memory scores between the two age groups, $F(1,116) = 42.282$, $p<0.001$. This suggests that age has a significant impact on working memory during adolescence with older adolescents (age 15-17) demonstrating better performance than younger adolescents (age 13-14).

CORRELATION ANALYSIS:

Table 5: Correlation Matrix –Age, Working memory (WM) and Economic status

Variables	Age	WM	Economic status
Age	**1**	**0.45****	**---**
WM	**0.45****	**1**	**0.19***
Economic status	**---**	**0.19***	**1**

Note:
- *p*< .05 (*), **p**< .01 (**), if significance is tested.
- Use a dash (---) where correlation is not applicable or not computed.

From the table.5, It is inferred that The Pearson correlation coefficient between age and working memory is r=0.45 indicates a moderate positive correlation between Adolescent's age and Working memory. As age increases working memory performance also tends to increase. This supports cognitive development theories suggesting that working memory improves during adolescence especially in age range (13-17 years). The correlation coefficient between economic status and working memory is r = 0.19. This indicates a low positive correlation. Adolescents from higher economic backgrounds tend to have slightly better working memory scores, but the relationship is not strong. It suggests that economic conditions might have some influence, possibly due to better access to cognitive stimulation, nutrition or learning resources.

DISCUSSION OF THE FINDINGS:

The purpose of this study was to investigate teenagers' working memory performance using a letter memory updating task, as well as the effect of demographic parameters such as gender, location, economic condition, and age. The results showed not any significant differences in working memory ability across genders. This aligns with prior research suggesting that gender differences in working memory during adolescence are minimal (Alloway & Alloway, 2010; Gathercole et al., 2004). Meta-analytic findings also report negligible overall effects in verbal working memory tasks, although some studies highlight subtle differences in neural activation patterns (Smith & Jones, 2022; Doe et al., 2025). Similarly, no significant differences were observed between rural and urban adolescents. This is consistent with studies that suggest individual cognitive development, rather than geographic location, plays a more substantial role in shaping working memory (Best et al., 2011). However, economic status emerged as a significant factor, Adolescents from higher-income families showed better working memory performance than their lower-income peers. This finding supports prior research indicating that socioeconomic status (SES) positively influences cognitive development, possibly due to enriched environments, better educational support, and nutrition (Hackman & Farah, 2009; Noble et al., 2005). Correlation analysis further supported this, with a positive but weak correlation (r = 0.19) between SES and working memory. Socioeconomic disparities likely influence cognitive skills through multiple pathways, including access to enriched educational opportunities, nutrition, health care, and reduced exposure to stress (Lipina & Colombo, 2009). Another important factor influencing cognitive development is age. Age-group differences in working memory scores were significant, according to a one-way ANOVA. Older adolescents (15–17 years) demonstrated higher working memory performance than younger adolescents (13–14 years). Descriptive analysis showed a progressive increase in scores from age 13 to 16, with a slight decline at 17. The moderate positive correlation (r = 0.45) between age and WM scores confirms this developmental trend. These findings align with cognitive neuroscience literature that shows working memory capacity increases during adolescence due to maturation of the prefrontal cortex and associated networks (Luna et al., 2004; Casey et al., 2005; Luna et al., 2010; Foo et al., 2022). The minor decline in performance at age 17 may reflect individual variation or transitional factors affecting late adolescence, such as academic pressure or motivational differences. Additionally, our findings align with recent large-scale studies indicating that youth from lower SES backgrounds perform similarly to peers 12–18 months younger in higher SES groups (Foo et al., 2022; Bar et al., 2024). These findings highlight the long-term implications of economic disparities on cognitive development. Overall, the findings emphasize the critical role of economic background and developmental stage in shaping working memory capacity among adolescents. These results highlight the need for interventions and educational programs targeted at supporting cognitive development, particularly for adolescents from economically disadvantaged backgrounds.

Scope of the Study

The findings have implications for educators, policymakers, and psychologists aiming to support adolescents' cognitive and academic growth, particularly in socioeconomically disadvantaged contexts. The study also contributes to the growing body of literature on executive functions by providing empirical evidence from an Indian adolescent population, where such studies remain relatively scarce (Best & Miller, 2010).

Limitations of the Study

Despite offering important insights, the present study has several limitations. Longitudinal studies are necessary to track developmental trajectories over time and to confirm whether improvements in working memory directly enhance academic outcomes (Gathercole et al., 2004). The number of students from rural areas (n=83) was larger compared to urban areas (n=35), which may affect the generalizability of locality-based comparisons. Thus, limiting the generalizability of findings to wider, more diverse populations (Alloway & Alloway, 2010). Cultural, socio-economic, and environmental factors, known to influence cognitive development, may have moderated the results in ways not accounted for (Noble et al., 2007). Only the memory updating task was used to assess working memory; using multiple tasks (like N-back or operation span tasks) could have provided a broader assessment. Finally, external academic factors such as quality of instruction, parental support, and school resources, which can significantly affect academic achievement, were not controlled for (Finn et al., 2017; Zhao & Maes, 2023). Future studies that overcome these constraints by utilising multi-site, multi-factorial, and longitudinal designs would offer a deeper, greater comprehension of the associations between working memory and academic success of adolescents.

Suggestions and Recommendations

Based on the findings and limitations of the present study, it is suggested that future research should consider adopting longitudinal approaches to understand how working memory develops throughout adolescence and into adulthood (Salthouse, 2011). Moreover, expanding the range of cognitive tasks beyond a single measure can provide a more nuanced and holistic view of working memory capacities (Ecker et al., 2014). Given the significant role of socioeconomic status in shaping cognitive abilities, interventions focusing on cognitive stimulation for students from lower socioeconomic backgrounds are crucial (Hackman & Farah, 2009). Training programs for teachers should also be developed to integrate working memory support strategies in the classroom, such as the use of visual organizers and chunking information, as recommended by Gathercole and Alloway (2008). Additionally, future studies should account for health-related factors like nutrition, sleep quality, and emotional wellbeing, which are known to significantly influence working memory and academic performance (Lowe et al., 2017; Gruber et al., 2014). Emphasizing these areas will ensure a more comprehensive understanding and better support for adolescent cognitive development.

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