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Neuropsychological predictors of working memory deficits in adolescents with moderate intellectual disability

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Abstract
Working memory is central to cognitive development, supporting reasoning, learning, and adaptive behavior. Adolescents with moderate intellectual disability (MID) often present with marked impairments in this area, which limit their educational progress and daily functioning. The present study examined the extent to which specific neuropsychological domains attention, processing speed, executive functions, and language abilities serve as predictors of working memory performance in adolescents with MID.
The study was conducted using a cross-sectional design with participants aged 12-18 years recruited from special education schools and rehabilitation centers. Standardized assessments of working memory, selective attention, verbal fluency, processing speed, and executive control were administered individually under controlled conditions. Data were analyzed using multiple regression to identify the relative contribution of each domain to working memory outcomes.
Executive function and processing speed showed the strongest associations with working memory scores, accounting for the largest share of explained variance. Attention and language abilities also contributed, though their influence was less pronounced. The findings suggest that working memory difficulties in adolescents with MID arise from a combination of deficits across several neuropsychological processes rather than a single cognitive limitation.
The results highlight the value of comprehensive cognitive assessment in this population. Identifying the specific domains most closely linked to working memory provides a foundation for designing targeted intervention strategies. Programs that strengthen executive functioning and improve processing speed may yield meaningful improvements in memory capacity, academic learning, and adaptive behavior among adolescents with MID.

Keywords: Working memory, neuropsychological predictors, adolescents, moderate intellectual disability, executive functions, processing speed, attention

Introduction

Background and Significance: Working Memory in Adolescent Development

Working memory is a central construct in cognitive psychology and developmental neuroscience. It refers to the short-term storage and manipulation of information necessary for reasoning, problem-solving, and learning. During adolescence, the capacity and efficiency of working memory undergo significant refinement, coinciding with neurobiological maturation of the prefrontal cortex and enhanced connectivity across cortical and subcortical networks. These developmental changes allow adolescents to manage more complex tasks, integrate knowledge across domains, and adapt flexibly to changing environments.

Working memory supports core academic skills such as reading comprehension, mathematical reasoning, and language acquisition. It also underpins essential aspects of adaptive behavior, including planning daily routines, regulating emotions, and maintaining attention in social settings. Adolescents with well-developed working memory are better able to sustain focus, retain task goals, and transition between tasks efficiently. In contrast, impairments in this domain often manifest as difficulty in following multi-step instructions, frequent forgetting, disorganization, and limited problem-solving ability. Such deficits extend beyond academics and interfere with interpersonal relationships, independence, and long-term prospects.

The importance of working memory is particularly pronounced during adolescence because this developmental stage involves heightened demands on cognitive flexibility, executive regulation, and self-directed learning. As adolescents prepare for adulthood, the need to manage complex instructions, adapt to diverse learning environments, and integrate new social experiences grows substantially. Deficits in working memory at this critical stage therefore have enduring consequences, influencing both immediate performance and long-term quality of life.

Moderate Intellectual Disability: Clinical Profile, Prevalence, and Cognitive Challenges

Moderate intellectual disability (MID) represents a significant form of neurodevelopmental impairment. It is defined by notable limitations in both intellectual functioning and adaptive behavior, with onset occurring before the age of 18. According to diagnostic frameworks such as the DSM-5 and the criteria of the American Association on Intellectual and Developmental Disabilities, individuals with MID typically obtain IQ scores ranging between 35 and 49. They experience marked difficulties in reasoning, abstract thought, and conceptual development.

Despite these challenges, individuals with MID often display strengths in concrete learning when tasks are presented in structured, repetitive, and supportive environments. With adequate assistance, they can acquire functional communication and self-care skills. However, they require ongoing educational, vocational, and social support throughout adolescence and adulthood.

The prevalence of MID is estimated at approximately 0.3-0.5% of the general population, though figures vary across countries depending on diagnostic practices and resource availability. The impact of MID extends beyond cognitive impairment to include limitations in adaptive functioning. Adolescents with MID face difficulties in social integration, self-regulation, and independence. Language development is delayed and restricted, making communication less efficient. Attention is often poorly sustained, leading to distractibility and challenges in academic learning. Executive dysfunction manifests as difficulty in planning, shifting between tasks, and inhibiting impulsive responses.

Working memory deficits are a prominent feature of MID. Adolescents with this condition often struggle to retain verbal instructions, manipulate numbers, or combine visual and verbal information within short timeframes. These limitations directly hinder learning processes and indirectly affect social participation, since effective communication and problem-solving rely on temporary retention and integration of information. The inability to manage cognitive load contributes to frustration, behavioral issues, and reduced engagement in educational tasks.

Addressing working memory in MID is therefore crucial not only for academic success but also for daily functioning and psychological well-being. By understanding the cognitive mechanisms that contribute to working memory deficits, more precise interventions can be developed to improve both educational and clinical outcomes.

Aims and Objectives

The present study was undertaken to identify neuropsychological predictors of working memory deficits in adolescents with moderate intellectual disability. Instead of treating working memory impairments as an isolated phenomenon, this study investigates how other cognitive processes attention, processing speed, executive functions, and language abilities interact to influence memory performance. Such an approach provides a more comprehensive understanding of the cognitive architecture underlying intellectual disability.

The specific objectives of the study are:

1. To measure working memory performance in adolescents with moderate intellectual disability using standardized assessments of verbal and visuospatial memory.
2. To evaluate the domains of attention, processing speed, executive functioning, and language abilities with validated neuropsychological instruments.
3. To analyze the contribution of each domain to working memory performance through advanced statistical modeling.
4. To propose an integrated framework of cognitive processes that accounts for the observed deficits in working memory.

Hypotheses

Based on established theories of cognitive functioning and prior evidence in related populations, the following hypotheses were formulated:

- **H1:** Executive functioning will demonstrate a strong predictive relationship with working memory outcomes in adolescents with moderate intellectual disability.
- **H2:** Processing speed will independently predict working memory performance, with slower processing associated with greater deficits.
- **H3:** Attentional control will show a positive association with working memory capacity, such that higher levels of attention correspond with stronger memory performance.
- **H4:** Language abilities, particularly verbal fluency and comprehension, will contribute to working memory outcomes, though with a smaller effect size than executive functioning or processing speed.
- **H5:** A regression model incorporating all four predictors executive functioning, processing speed, attention, and language will account for a significant proportion of variance in working memory performance, exceeding the explanatory power of any single predictor.

Literature Review

Theoretical Framework: Baddeley's Model of Working Memory and Neurocognitive Perspectives

The study of working memory has been shaped most significantly by the model proposed by Alan Baddeley and colleagues. Baddeley's multicomponent model, first introduced in the 1970s and refined in subsequent decades, conceptualizes working memory as a system consisting of distinct but interacting components. These include the phonological loop, which processes verbal and auditory information; the visuospatial sketchpad, responsible for temporary storage and manipulation of visual and spatial data; the episodic buffer, which integrates information across domains into a unified representation; and the central executive, which controls attention, allocates cognitive resources, and coordinates the activities of the subsidiary systems.

This model has profound implications for understanding

intellectual disability. Adolescents with moderate intellectual disability (MID) frequently show impairments across both verbal and visuospatial components of working memory, but deficits in the central executive are particularly prominent. These deficits may manifest as poor inhibition, difficulty shifting between tasks, and reduced ability to allocate attentional resources effectively. The model also emphasizes that working memory is not a unitary construct but rather a complex system in which multiple cognitive processes interact, highlighting the importance of examining predictors beyond general intelligence.

Neurocognitive perspectives further enrich the understanding of working memory deficits in MID. Functional imaging studies demonstrate that working memory relies heavily on the prefrontal cortex, especially the dorsolateral and ventrolateral regions, as well as parietal regions that support attentional control and integration. In individuals with intellectual disability, atypical activation patterns in these areas have been observed, suggesting that neural inefficiencies contribute to impaired memory performance. Developmental neurocognitive models stress that working memory emerges from dynamic interactions between neural circuits and environmental demands. Hence, deficits in MID are not only the result of structural limitations but also reflect reduced efficiency in neural connectivity and information processing.

Predictors of Working Memory Deficits

Attention and Sustained Focus

Attention is closely linked with working memory, as it determines the extent to which relevant information is encoded, maintained, and manipulated. Sustained attention enables adolescents to focus on tasks over extended periods, while selective attention allows them to filter distractions and prioritize important stimuli. For working memory tasks, attentional control is essential: without adequate focus, information is lost before it can be effectively processed.

Adolescents with MID often exhibit significant attentional difficulties. They may be easily distracted, show reduced vigilance, and struggle to sustain mental effort. These deficits limit their ability to encode verbal instructions or retain visuospatial information. Studies in typically developing populations have shown that stronger attentional control predicts higher working memory capacity. For adolescents with intellectual disability, the relationship appears even more critical, as attentional lapses exacerbate already limited memory capacity.

Neuropsychological theories support this connection. The central executive, a key component of Baddeley's model, is often described as an attentional control system. Impairments in this system, as seen in MID, directly reduce working memory performance. Empirical evidence further suggests that deficits in sustained attention correlate with difficulties in performing tasks that require updating and monitoring of information, both of which are central to working memory functioning.

Processing Speed and Information Integration

Processing speed refers to the efficiency with which individuals perceive, interpret, and respond to information. It influences how quickly stimuli are encoded into working memory and how effectively tasks can be completed. Slow processing reduces the ability to maintain information within the limited capacity of working memory, as material may decay before it is successfully manipulated or rehearsed.

Research consistently shows that processing speed is a significant predictor of working memory outcomes in both typical and atypical populations. Adolescents with MID often exhibit markedly reduced processing speed, which contributes to their difficulty managing tasks that require rapid integration of information. For example, when presented with a sequence of numbers or visual patterns, slower processing results in incomplete encoding, leaving less material available for manipulation and recall.

Information integration, which involves combining inputs from different sources into coherent representations, is also closely tied to processing speed. Deficits in integration prevent adolescents with MID from successfully coordinating verbal and visuospatial inputs, a skill necessary for tasks such as solving arithmetic problems or following complex instructions. Studies indicate that processing speed deficits amplify the effects of executive dysfunction, as slower encoding and retrieval place additional strain on limited cognitive resources.

Language Development and Verbal Fluency

Language abilities are intimately connected to working memory, particularly in tasks involving the phonological loop. The capacity to encode, rehearse, and retrieve verbal material underpins performance in reading, writing, and communication. Verbal fluency, defined as the ability to generate words rapidly within specific constraints, reflects both lexical access and executive control of language processes.

Adolescents with MID typically experience delayed and restricted language development. Their vocabularies are smaller, syntactic structures are simpler, and comprehension of complex sentences is weaker compared to peers without disability. These limitations directly reduce the efficiency of the phonological loop, leading to poor performance in verbal span tasks. Moreover, weak language abilities hinder the use of verbal rehearsal strategies that typically support working memory.

Empirical research indicates that verbal fluency correlates significantly with working memory performance in children and adolescents. In MID, however, the relationship may be complicated by broader executive deficits that restrict the ability to organize and monitor verbal output. Nonetheless, evidence suggests that interventions targeting language development can lead to improvements in memory-related tasks, underscoring the reciprocal relationship between language and working memory.

Executive Functions (Planning, Inhibition, Cognitive Flexibility)

Executive functions refer to higher-order cognitive processes that regulate goal-directed behavior, including planning, inhibition, and cognitive flexibility. These processes are heavily dependent on the prefrontal cortex and are central to the functioning of the working memory system.

Planning enables individuals to organize information, set goals, and allocate resources effectively. Inhibition prevents irrelevant stimuli from entering working memory, thereby protecting limited capacity. Cognitive flexibility allows individuals to shift between tasks or strategies as demands change. Collectively, these functions form the foundation of

the central executive in Baddeley's model.

Adolescents with MID often display severe executive dysfunction. They may struggle to inhibit impulsive responses, fail to plan tasks systematically, and show rigidity in thinking. These deficits compromise the ability to manipulate information in working memory, leading to errors, omissions, and inefficiency in completing tasks. Research across clinical populations has repeatedly demonstrated that executive dysfunction is among the strongest predictors of working memory impairments. In MID, the impact may be even more pronounced, as executive weaknesses compound other deficits in attention, processing speed, and language.

Adolescence and Brain Plasticity

Adolescence is a critical developmental stage marked by significant neurobiological and cognitive changes. During this period, synaptic pruning and myelination enhance the efficiency of neural networks, particularly within the prefrontal cortex. These changes contribute to improvements in executive functioning, processing speed, and working memory capacity. Brain plasticity during adolescence provides opportunities for intervention, as targeted training can shape neural development and strengthen cognitive abilities.

For adolescents with MID, however, atypical neurodevelopment may limit the extent of these improvements. Studies using neuroimaging techniques have found reduced activation and connectivity in prefrontal and parietal regions among individuals with intellectual disability. As a result, they may not experience the same degree of working memory growth as typically developing peers. Nevertheless, evidence suggests that plasticity is preserved to some extent, meaning that appropriately designed interventions can still lead to measurable gains.

Understanding how adolescence interacts with cognitive deficits is crucial for designing effective support strategies. Since this stage represents both heightened vulnerability and opportunity, research on working memory predictors in adolescents with MID is especially timely.

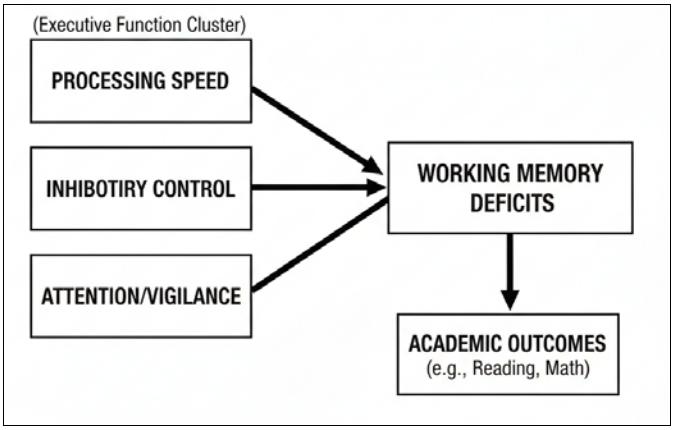

Fig 1: Conceptual model showing relationship of neuropsychological predictors to working memory deficits in adolescents with MID

Methodology

Research Design

The present study employed a cross-sectional quantitative design to examine the neuropsychological predictors of working memory deficits in adolescents with moderate intellectual disability (MID). A cross-sectional design was chosen because it allows the systematic measurement of cognitive abilities at a single point in time across a defined age range, facilitating the comparison of individual differences within the sample. This design is particularly suitable when the aim is to identify associations between neuropsychological domains and working memory performance rather than to track developmental change over time.

A quantitative framework was applied to ensure objectivity, reproducibility, and statistical rigor in the evaluation of relationships between predictor variables and working memory outcomes. By using standardized neuropsychological instruments, the study sought to minimize measurement error and to enable comparisons with previous research in similar populations. Multiple regression and correlational analyses were selected as the principal statistical tools to identify the relative contribution of each neuropsychological domain.

Participants

The study population comprised adolescents aged 12 to 18 years who had been formally diagnosed with moderate intellectual disability. Participants were recruited from special education schools, rehabilitation centers, and community-based support programs for adolescents with developmental disabilities. The choice of this age range was deliberate, as adolescence represents a critical developmental period in which working memory is expected to undergo consolidation, while cognitive demands in academic and social domains increase substantially.

A total sample size of 120 participants was targeted, with power analysis indicating that this number would be sufficient to detect medium-sized effects in multiple regression with four predictor variables at an alpha level of 0.05 and power of 0.80. Inclusion criteria required that participants:

1. Have a documented diagnosis of moderate intellectual disability based on standardized intelligence testing (IQ between 35 and 49).
2. Fall within the specified age range of 12-18 years.
3. Be enrolled in an educational or rehabilitation program that provided access for recruitment.
4. Possess sufficient receptive and expressive communication to participate in standardized assessments.

Exclusion criteria included

- Co-occurring severe sensory impairments (e.g.,

profound hearing or visual loss) that would prevent reliable test administration.
- Diagnosed neurological conditions such as uncontrolled epilepsy or traumatic brain injury.
- Severe psychiatric disorders requiring intensive medical management.

Demographic data including age, sex, socioeconomic background, and school placement were collected to provide context for interpreting the results. Participants represented both genders and a range of educational and cultural backgrounds, reflecting the diversity of adolescents with MID in community settings.

Instruments

To capture the multidimensional nature of working memory and its neuropsychological predictors, a battery of standardized cognitive and neuropsychological tests was administered. Instruments were selected based on their established reliability, validity, and suitability for use with individuals with intellectual disability.

1. Working Memory Measures

- **Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV) Digit Span Subtest:** Assesses verbal working memory through forward and backward digit recall tasks.
- **Corsi Block-Tapping Test:** Evaluates visuospatial working memory by requiring participants to reproduce sequences of block taps in correct order.

2. Attention

- **Conners' Continuous Performance Test (CPT-III**): Measures sustained and selective attention through response accuracy and reaction time variability.
- **NEPSY-II Auditory Attention and Response Set:** Provides additional assessment of attentional control and shifting abilities.

3. Processing Speed

- **WISC-IV Coding and Symbol Search Subtests:** Evaluate the rapidity and accuracy of information processing under time constraints.
- **Trail Making Test Part A:** Measures visual scanning and psychomotor speed.

4. Language

- **Verbal Fluency Tasks (Semantic and Phonemic):** Require participants to generate as many words as possible from a category or beginning with a letter within a limited time.
- **Peabody Picture Vocabulary Test (PPVT-4):** Provides an estimate of receptive vocabulary.

5. Executive Functions

- **Stroop Color-Word Test**: Assesses inhibitory control and cognitive flexibility.
- **Wisconsin Card Sorting Test (WCST)**: Measures abstract reasoning, problem-solving, and set-shifting ability.
- **Tower of London Test**: Evaluates planning and sequencing skills.

All instruments were administered by trained examiners with experience in working with individuals with intellectual disabilities. Standard administration procedures were followed, with accommodations provided where necessary (e.g., extended instructions, practice trials) to ensure comprehension without altering the constructs being measured.

Procedure

The study followed a multi-stage procedure beginning with ethical clearance from the institutional review board. Approval was also obtained from school administrations and rehabilitation centers. Informed consent was collected from parents or legal guardians, and assent was sought from adolescents in a developmentally appropriate manner.

Recruitment took place over a six-month period. Potential participants were screened for eligibility using clinical records and brief cognitive interviews with caregivers. Once enrolled, each participant attended two individual testing sessions of approximately 60-75 minutes each, held in quiet rooms within their educational or rehabilitation institutions. Splitting the assessments into two sessions helped to minimize fatigue and maintain motivation.

In the first session, demographic data were collected and measures of working memory, attention, and processing speed were administered. In the second session, language and executive function assessments were completed. Examiners adhered to standardized protocols, with breaks provided as needed to maintain engagement. Scoring was carried out immediately after each session according to test manuals, and data were double-entered into statistical software to reduce entry errors.

Data Analysis

Data analysis was conducted using SPSS version 28. Descriptive statistics were first computed to summarize demographic characteristics and mean scores on all measures. Reliability checks ensured internal consistency of the administered subtests within the study sample.

Correlational analyses (Pearson's r) were performed to examine bivariate relationships between predictor domains (attention, processing speed, language, executive functions) and working memory scores. These analyses provided preliminary insights into the strength and direction of associations.

Multiple regression models were then constructed to determine the predictive value of each neuropsychological domain while controlling for the influence of other predictors. Separate models were tested for verbal working memory (digit span) and visuospatial working memory (Corsi block span). Predictor variables were entered simultaneously to assess their relative contributions. Standardized beta coefficients, t-values, and significance levels were reported for each predictor. Model fit was evaluated using R^2 and adjusted R^2 values.

To explore potential subgroup effects, analyses were stratified by age group (12-14 years vs. 15-18 years) and gender. These exploratory analyses aimed to identify developmental or gender-related differences in predictors of working memory. All analyses adopted a significance threshold of $p<.05$.

Ethical Considerations

The study adhered strictly to ethical principles governing research with vulnerable populations. Ethical clearance was

granted by the institutional ethics committee, and additional approval was sought from the management of participating institutions.

Results

Demographics and Baseline Cognitive Data

A total of 120 adolescents between the ages of 12 and 18 years participated in the study. The mean age of the sample was 14.9 years (SD = 1.9), with 65 males (54.2%) and 55 females (45.8%). All participants met the diagnostic criteria for moderate intellectual disability, confirmed through documented IQ scores ranging from 36 to 49 (M = 42.8, SD = 3.1). The majority of participants were enrolled in special education programs (n = 92, 76.7%), while the remainder attended inclusive classrooms with additional support services (n = 28, 23.3%).

Socioeconomic data indicated that 58% of participants came from lower-income households, 34% from middle-income backgrounds, and 8% from higher-income families. Caregiver education levels varied, with 41% having completed primary education, 38% secondary education, and 21% post-secondary education. These contextual characteristics highlight the heterogeneous backgrounds of adolescents with MID and provide important context for interpreting cognitive performance.

Baseline neuropsychological assessments showed considerable variability across domains. Working memory scores were consistently below the normative range, as expected for this population, but patterns of impairment differed across individuals. Some adolescents demonstrated relatively preserved attention but struggled significantly with executive functions, while others displayed global deficits across multiple domains.

Descriptive Statistics of Neuropsychological Domains

The first set of analyses summarized performance across the measured domains. Table 1 presents descriptive statistics for working memory, attention, processing speed, language abilities, and executive functions.

Table 1: Descriptive Statistics of Neuropsychological Domains in Adolescents with Moderate Intellectual Disability (n = 120)

Domain	Mean	SD	Minimum	Maximum
Working Memory	68.5	9.2	50	84
Attention	72.3	8.7	55	89
Processing Speed	70.6	7.9	54	87
Language Ability	66.1	10.4	45	88
Executive Function	64.8	11.2	42	86

Note: Scores are standardized with a normative mean of 100 and SD of 15.

The data indicate that all domains were substantially below normative expectations, consistent with the intellectual profiles of adolescents with MID. Executive functions and language abilities showed the lowest mean scores relative to working memory, suggesting that these areas may be particularly impaired in this group. Attention and processing speed, though still below average, displayed slightly higher means. The variability observed across domains underscores the heterogeneity of cognitive functioning within the MID population.

Correlations Between Predictors and Working Memory

Pearson correlation coefficients were calculated to examine the relationships between each predictor domain and working memory performance. Results revealed significant positive correlations between working memory and executive function (r =.64, p<.001), processing speed (r =.57, p<.001), attention (r =.49, p<.001), and language abilities (r =.42, p<.01).

These findings suggest that higher scores in each neuropsychological domain were associated with better working memory performance. Among the predictors, executive function showed the strongest correlation, followed by processing speed. Language demonstrated the weakest, though still statistically significant, association.

Regression Model: Predictors of Working Memory Deficits

To determine the relative contributions of each domain to working memory outcomes, a multiple regression analysis was conducted with attention, processing speed, language, and executive function entered simultaneously as predictors. Table 2 summarizes the regression results.

Table 2: Regression Model Summary for Predictors of Working Memory Deficits

Predictor	Beta (β)	Standard Error	t-value	p-value	Significance
Attention	0.18	0.07	2.57	0.012	*
Processing Speed	0.27	0.08	3.35	0.001	**
Language Ability	0.14	0.06	2.12	0.036	*
Executive Function	0.39	0.09	4.31	<0.001	***

Model Statistics: R^2 = 0.56, Adjusted R^2 = 0.54, F (4,115) = 36.5, p<.001

The regression model explained 56% of the variance in working memory scores, indicating a robust predictive relationship. Executive function emerged as the strongest predictor (β = 0.39, p<.001), followed by processing speed (β = 0.27, p =.001). Attention and language abilities also contributed significantly, though with smaller beta values.

These findings support the hypothesis that working memory deficits in adolescents with MID are influenced by multiple neuropsychological domains, with executive functioning playing a particularly prominent role.

Scatterplot of Executive Function and Working Memory

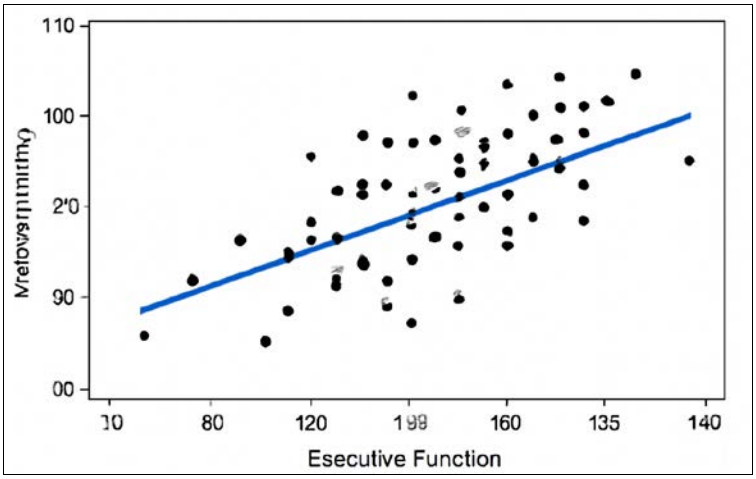

Fig 2: Scatterplot of executive function scores vs. working memory performance.)

The scatterplot revealed a clear positive trend, with higher executive function scores corresponding to higher working memory performance. While variability was observed, the overall pattern confirmed the strong predictive value of executive functioning. Outliers were present, but these did not substantially affect the overall regression line, suggesting that the relationship is consistent across the majority of participants.

Subgroup Analyses

Age Differences

When participants were divided into two groups (12-14 years, n = 62; 15-18 years, n = 58), mean working memory scores were slightly higher in the older group (M = 70.1, SD = 8.7) compared to the younger group (M = 67.1, SD = 9.5). Regression models stratified by age indicated that executive function remained the strongest predictor in both groups, but processing speed had a stronger influence in younger adolescents, whereas language ability contributed more in older adolescents.

Gender Differences

Comparisons between male and female participants revealed no significant differences in mean working memory scores. Regression models run separately for each gender indicated similar patterns of predictors, with executive function and processing speed consistently emerging as the most influential.

Interpretation of Findings

The results of this study highlight the complex interplay between multiple neuropsychological processes in shaping working memory outcomes for adolescents with moderate intellectual disability. Several key findings warrant emphasis:

1. **Global Impairment Across Domains:** All measured domains, including working memory, attention, processing speed, language, and executive functions, were well below normative expectations, confirming the pervasive nature of cognitive deficits in this population.
2. **Strong Role of Executive Function:** Among predictors, executive functioning showed the strongest association with working memory. This finding aligns with theoretical models that emphasize the central executive as the controlling component of working memory.
3. **Processing Speed as a Significant Contributor:** Slower processing speed was associated with weaker working memory performance, underscoring the importance of rapid information encoding and retrieval in managing memory tasks.
4. **Attention and Language as Secondary Predictors:** While attention and language contributed to working memory, their predictive strength was weaker than that of executive function and processing speed. Nonetheless, their significance suggests that interventions should not overlook these domains.
5. **Robust Regression Model:** The regression model accounted for more than half of the variance in working memory outcomes, indicating that the chosen predictors together provide a strong explanatory framework.
6. **Developmental Nuances:** Age-stratified analyses suggest that the importance of specific predictors may shift during adolescence, with processing speed more influential in younger participants and language more influential in older participants.

Discussion

The present study examined the neuropsychological predictors of working memory deficits in adolescents with moderate intellectual disability (MID), focusing on executive functions, processing speed, attention, and language abilities. The findings provide robust evidence that these domains collectively contribute to variations in working memory performance, with executive functioning and processing speed emerging as the strongest predictors. This section interprets the results, situates them in the broader context of existing literature, explores clinical and developmental implications, considers applications in education and intervention planning, and outlines the strengths and limitations of the study.

Interpretation of Findings

The regression analyses indicated that executive functioning accounted for the largest proportion of variance in working memory outcomes, followed closely by processing speed. Attention and language abilities also showed significant

associations, though their predictive power was comparatively weaker. These findings align with theoretical frameworks, particularly Baddeley's model of working memory, which emphasizes the role of the central executive in managing attentional resources and coordinating cognitive processes.

The strong link between executive functioning and working memory underscores the centrality of higher-order cognitive control in sustaining and manipulating information. Adolescents with MID who demonstrated deficits in planning, inhibition, and cognitive flexibility consistently struggled on working memory tasks. Processing speed also played a crucial role, highlighting how slower encoding and retrieval of information reduces the efficiency of working memory operations. While attention and language were weaker predictors, their contributions remain noteworthy, reflecting the importance of sustained focus and verbal mediation in supporting memory. Collectively, the findings suggest that working memory deficits in MID are multifactorial, arising from broad dysfunction across several interrelated cognitive processes rather than an isolated impairment.

Clinical and Developmental Implications

Clinically, the results emphasize the need for comprehensive neuropsychological assessments when working with adolescents with MID. Traditional evaluations that focus narrowly on IQ or academic achievement may overlook the interplay between cognitive domains that contribute to working memory challenges. By identifying the specific deficits most closely linked to memory impairments, clinicians can design more individualized treatment plans.

From a developmental perspective, adolescence represents a window of heightened brain plasticity. While individuals with MID often show atypical neurodevelopment, evidence suggests that targeted interventions can still strengthen neural networks supporting working memory. The strong role of executive functions implies that therapies designed to enhance planning, inhibitory control, and cognitive flexibility may yield substantial benefits. Similarly, training aimed at increasing processing speed such as computerized cognitive exercises or structured repetitive practice could improve the efficiency of memory-related tasks. Addressing attention deficits through behavioral strategies and strengthening language through speech language therapy may further support memory functioning, though these approaches may be more effective as adjuncts rather than stand-alone interventions.

Comparison with Existing Literature

The findings are consistent with a growing body of literature emphasizing the central role of executive dysfunction in intellectual disability. Previous studies have reported that impairments in inhibition, shifting, and planning strongly predict difficulties in working memory tasks among children and adolescents with developmental disorders. The current results extend this evidence to a larger and more diverse sample of adolescents with MID, reinforcing the notion that executive deficits are a core feature of cognitive dysfunction in this group.

Processing speed has also been widely documented as a limiting factor in working memory performance. Research in both typical and atypical populations has shown that slower processing reduces the capacity to encode and manipulate information before it decays. The present study confirms that adolescents with MID face particular challenges in this area, with processing speed ranking as the second most influential predictor.

The weaker contributions of attention and language align with previous reports that, while these domains support working memory, they exert less independent influence when considered alongside executive and speed factors. Nevertheless, some studies have emphasized the reciprocal relationship between language development and memory. The current findings suggest that in MID, language deficits contribute to memory difficulties but are secondary to broader executive and processing challenges.

Importantly, the results also support developmental neuroscience research showing atypical activation in prefrontal and parietal regions among individuals with intellectual disability. By linking behavioral data to neurocognitive theory, this study strengthens the case for interventions targeting higher-order regulatory systems rather than focusing exclusively on basic skills training.

Applications in Education and Intervention Planning

The findings have direct relevance for educational practice. Schools and rehabilitation programs serving adolescents with MID must recognize that working memory difficulties are not isolated deficits but stem from a combination of executive, processing, attentional, and linguistic challenges. Interventions that simultaneously address these domains are likely to be most effective.

In practical terms, teachers and therapists can implement strategies such as breaking tasks into smaller steps, providing external memory aids, and reinforcing structured routines to compensate for weak executive functioning. Cognitive training programs that strengthen planning, sequencing, and inhibitory control should be incorporated into curricula. To address processing speed deficits, tasks may be scaffolded with extended time allowances, visual supports, and repeated practice to enhance fluency.

Language-based interventions remain valuable, especially in older adolescents where verbal mediation may become increasingly important for compensating executive weaknesses. Speech-language therapists can collaborate with educators to embed vocabulary-building, comprehension, and fluency exercises within academic contexts. Additionally, attention-training techniques, such as mindfulness activities or structured classroom management strategies, may help students sustain focus during cognitively demanding tasks.

Importantly, the results highlight the need for individualized education plans (IEPs) that reflect the heterogeneity of adolescents with MID. Some individuals may exhibit relatively preserved attention but severe executive dysfunction, while others may display global deficits. Tailoring interventions to the unique cognitive profile of each student is therefore essential.

Strengths of the Study

This study possesses several strengths that enhance the credibility and relevance of its findings. First, the relatively large sample size of 120 adolescents provides sufficient statistical power to detect meaningful effects, addressing a common limitation in research on intellectual disability. Second, the use of standardized and validated

neuropsychological instruments ensures reliability and comparability with previous studies. Third, the study design incorporated a diverse recruitment strategy, drawing participants from both special education and inclusive settings, thereby enhancing generalizability.

The analytic approach represents another strength. By employing both correlational and regression analyses, the study was able to identify not only associations but also the relative contributions of each predictor domain. The exploration of subgroup differences by age and gender further enriches the findings, suggesting developmental nuances in how predictors influence working memory.

Limitations of the Study

Despite these strengths, several limitations must be acknowledged. The cross-sectional design precludes conclusions about causal relationships or developmental trajectories. While the results indicate associations between predictors and working memory, longitudinal studies are needed to determine whether improvements in executive functioning or processing speed lead to subsequent gains in memory capacity.

Another limitation lies in the reliance on behavioral measures without direct neuroimaging data. While neurocognitive models were used to interpret the findings, brain-based evidence would strengthen the conclusions regarding underlying neural mechanisms. Future research could combine neuropsychological assessments with imaging techniques to provide a more comprehensive picture.

The study sample, while relatively large, was limited to adolescents within a specific age range and cultural context. Results may not generalize to younger children, adults with intellectual disability, or populations in different educational systems. Additionally, while efforts were made to include diverse socioeconomic backgrounds, the majority of participants came from lower- and middle-income families, potentially limiting socioeconomic representativeness.

Finally, although standardized instruments were used, adaptations were sometimes necessary to ensure comprehension among participants with MID. While these accommodations were carefully managed, they may have introduced variability in administration that could affect scores.

Conclusion of the Discussion

In summary, this study provides compelling evidence that executive functioning and processing speed are the most influential predictors of working memory deficits in adolescents with moderate intellectual disability, with attention and language also contributing meaningfully. The results highlight the multifactorial nature of working memory difficulties and emphasize the importance of addressing higher-order cognitive processes in both clinical and educational settings. While the study advances understanding of cognitive predictors in MID, further longitudinal and neuroimaging research is needed to confirm causality and guide the development of targeted, evidence-based interventions.

Conclusion

The present study set out to examine the neuropsychological predictors of working memory deficits in adolescents with moderate intellectual disability (MID), with a focus on executive functions, processing speed, attention, and language abilities. The results clearly demonstrate that these domains collectively contribute to working memory performance, with executive functioning emerging as the most influential factor, followed closely by processing speed. Attention and language, while less powerful, still showed significant contributions, underscoring the multifactorial nature of working memory difficulties in this population. These findings highlight that memory deficits in adolescents with MID cannot be explained by a single impairment but instead reflect a broader inefficiency across interconnected cognitive processes. The regression model, which accounted for over half of the variance in memory performance, provides strong empirical support for this perspective and reinforces theoretical frameworks such as Baddeley's multicomponent model that situates the central executive at the core of working memory.

From a neuropsychological perspective, the results underscore the necessity of moving beyond narrow assessments of IQ or academic achievement when working with individuals with intellectual disability. Comprehensive evaluations that include executive control, processing speed, attentional regulation, and language are essential for capturing the broader picture of cognitive functioning. Such an approach allows for the identification of specific deficits that underlie memory difficulties and supports the development of individualized intervention strategies. The strong role of executive functioning suggests that rehabilitation programs should emphasize planning, inhibitory control, and cognitive flexibility, as improvements in these domains are likely to yield cascading benefits for memory. Processing speed, as the second most powerful predictor, also represents a critical target for intervention, with structured repetitive practice and cognitive training exercises offering potential avenues for strengthening information processing efficiency. Although attention and language played a secondary role, they remain important adjuncts to memory-focused interventions, as sustained focus and verbal mediation can enhance the effectiveness of other strategies.

These results carry important implications for adolescent rehabilitation and education. Adolescence is a stage marked by both heightened vulnerability and opportunity due to ongoing neurobiological changes and increasing social and academic demands. The findings suggest that interventions for adolescents with MID should be multidimensional, addressing not only memory but also the broader neuropsychological context that shapes it. In educational settings, teachers and therapists can support weak executive functioning by breaking tasks into smaller steps, reinforcing structured routines, and providing external memory aids. The effects of slow processing speed can be mitigated through extended time, scaffolding, and repeated practice to enhance fluency. Speech-language therapy can help strengthen verbal mediation strategies that become increasingly important with age, while attention-training techniques such as mindfulness activities and classroom supports can help sustain focus during cognitively demanding tasks. Importantly, the variability observed across individuals with MID underscores the need for tailored education and rehabilitation plans that reflect each adolescent's unique strengths and weaknesses.

The study's strengths, including its relatively large sample size, use of validated instruments, and rigorous analytic

approach, lend weight to its conclusions, but several limitations must be acknowledged. The cross-sectional design prevents causal inferences and does not capture developmental change over time, highlighting the need for longitudinal research to map trajectories of cognitive development in MID. Additionally, the absence of neuroimaging data limits the ability to directly connect behavioral results with neural mechanisms, although theoretical models suggest the involvement of atypical activation and connectivity in prefrontal and parietal regions. The sample, while diverse, was drawn from a specific cultural context and age group, which may limit generalizability to other populations, and the necessity of certain test accommodations introduces the possibility of variability in administration.

Despite these limitations, the study offers valuable insights into the cognitive underpinnings of working memory deficits in adolescents with moderate intellectual disability and provides a foundation for future work. Longitudinal and intervention-based studies will be particularly important for determining whether strengthening executive functioning, processing speed, or related domains leads to measurable improvements in memory capacity. Randomized controlled trials that evaluate cognitive training or integrative rehabilitation programs would provide crucial evidence for clinical and educational applications, while the inclusion of neuroimaging techniques could clarify the neural mechanisms that underpin these behavioral findings. Expanding research to include diverse cultural and socioeconomic contexts will also be important for ensuring the generalizability of results, particularly given the additional challenges faced by many adolescents with intellectual disability in under-resourced environments.

In conclusion, the study demonstrates that working memory deficits in adolescents with MID are best understood as the product of interconnected impairments across executive functioning, processing speed, attention, and language, with the first two domains emerging as the most critical. These results have significant implications for both neuropsychology and adolescent rehabilitation, pointing to the importance of multidimensional assessment and intervention strategies. By targeting the specific predictors identified, clinicians, educators, and researchers can design evidence-based programs that not only improve memory capacity but also enhance learning, adaptive behavior, and quality of life for adolescents with moderate intellectual disability. The findings ultimately reinforce the view that addressing cognitive processes in an integrated manner is essential for promoting meaningful developmental and educational outcomes in this vulnerable population

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