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Articles

The Effect of Working Memory on Social Skills in Male Children with Adhd: A Structural Equation Model

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Abstract

ADHD is a nosological condition linked to impaired brain maturity, especially at the frontal temporal level, which generates neurocognitive behavioral and social alterations. Previous research has shown that ADHD is associated with deficits in executive functions, including working memory, which is relevant for regulating behavior and social interactions. This study analyzed the capacity of working memory as an explanatory element of social skills in schoolchildren diagnosed with ADHD, through a structural equation model. A sample of N = 250, males, diagnosed with ADHD, in school, aged between 9 and 12 years old, was used. The sampling was probabilistic. The structural equation model was developed in RCran 4.3.2 software; the social skills variable (endogenous) was measured with 6 observable variables (interaction with authority figures, interaction with opposite sex, being in evidence, assertive expression of annoyance, displeasure, interaction with strangers and acting in public), using the CANSO-N24 questionnaire. The working memory variable (exogenous) was measured with 5 observable variables (digits, letters/numbers, color, word and word/color), and WIS-IV and Stroop tests were applied. The model converged after 73 iterations; a p-value < 0.05 was obtained in the Chi-square statistic, resulting in a fitted model. A positive covariance (0.17) was obtained between working memory and social skills, and a P(>|z|) of 0.379, indicating a low significance. This study tested the theoretical prediction that better working memory would correlate with better social skills in schoolchildren diagnosed with ADHD. These results indicate that while there is a positive relationship, working memory is not the only factor explaining social skills in ADHD. This supports the theory that multiple factors, including other mental processes, genetic, and environmental influences, contribute to social skills development in ADHD.

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1. Introduction

Neurodevelopmental disorders encompass nosological conditions that are linked to deficits in brain maturation and neurocognitive functioning; these generate a negative impact on personal, school, and social dimensions (American Psychiatric Association - APA, 2021; Filippello et al., 2013; Operto et al., 2021). Research indicates that this categorical group of childhood-onset, presents a prevalence of 9.4%, with Attention Deficit Hyperactive Disorder (ADHD) being the most diagnosed with a percentage of 5.36% (Kofler et al., 2019). In European countries, a prevalence of 6.8% among infants and adolescents has been reported; concerning the school child population, 5% is indicated (Carballal Mariño et al., 2018; Catalá-López et al., 2012), in Latin America affects 8 to 18% of infants (Cervantes-Henriquez et al., 2021). From an early age, characteristics such as difficulties in selective, sustained, and divided attention; high energy and activity, quick and frequent responses, and fluent and abundant verbal communication are observed. These traits can influence executive functions and pedagogical and experiential learning (Nejati, 2020; Patros et al., 2017; Quintero-López et al., 2023).

The neurobiology of ADHD indicates differences in brain structure within cortical and subcortical regions (Hermosillo et al., 2020). Neurophysiological studies have shown variations in brain maturation, with a 3% to 5% lower total volume (Cardillo et al., 2020; Greven et al., 2015). Differences in neuronal activity in the hemispheres and corpus callosum affect inhibitory responses, leading to variations in white matter tracts and physiological functioning in the striatal network, cerebellum, and some basal ganglia; these differences can influence dendritic and axonal growth at the frontotemporal level (Castellanos & Proal, 2012; Pitzianti et al., 2017). Research has reported that the basal ganglia-thalamocortical circuitry presents variations that can affect inhibitory vigilance (Berger et al., 2021; Owens et al., 2021). In ADHD, it is relevant to consider not only neurocognitive aspects but also the impact on social relationships. Integrating a transdiagnostic approach, which considers shared processes and comorbidity across mental health conditions, provides a comprehensive framework. This approach allows for more effective treatment strategies that address the multifaceted nature of ADHD and its frequent co-occurrence with other conditions (Dalgleish et al., 2020; Scull, 2021).

Executive functions are conceived as neurocognitive abilities that regulate, control, and plan behavior and cognition, they are defined as those mental abilities necessary to establish creative, self-regulatory and social behaviors, focused on processes of action, planning, inhibition, Working Memory (WM) and problem-solving; they facilitate the achievement of future-oriented goals (Gordon & Hinshaw, 2020; Navarro-Soria et al., 2020). ADHD is linked with deficits in

these capacities, whose primary role is to self-regulate in social interaction. The main executive functions altered in ADHD are planning, inhibition, mental flexibility and WM (Landínez-Martínez et al., 2022; Mukherjee et al., 2021; Pineda-Alhucema et al., 2018).

WM has been defined as a neurocognitive process that allows storing, encoding and perseverating information; from the Baddeley-Hitch model, it is conceived as a temporary storage system to maintain, update and manipulate stimuli for short periods to align behaviors in cognitive activities (Simone et al., 2018). This approach has been widely employed as a theoretical reference in scientific publications aimed at identifying the characteristics of WM (Barreyro et al., 2017; Gremillion et al., 2018), from this theoretical approach WM is hierarchized into three categories; the first is responsible for monitoring attention (central executive); the second, for processing information verbally (phonological loop) and the third for processing visuospatial information (visuospatial agenda), which together allow the coordination of activities simultaneously (Eckrich et al., 2019; Wang et al., 2018). However, it is important to note that many theories of WM lack parsimony in their exposition, as highlighted by Myles and Guy Browne Johnson (2023) and Merlo et al. (2022). These theories often introduce unnecessary complexity without clear empirical support, which complicates their practical application. Kasper et al. (2012) conducted a meta-analysis that examined the extent of WM deficits in children with ADHD, reporting significant effect sizes. Specifically, they found a large effect size of 0.74 for visuospatial working memory (VS) and 0.69 for phonological working memory (PH), indicating that children with ADHD perform worse on these tasks compared to typically developing peers. The study highlighted significant variability in effect sizes, influenced by factors such as the proportion of females in the sample, the age of the participants, the number of trials per set size, and the demands placed on the central executive. By incorporating these systematic reviews, we reduce the risk of selective reporting and provide a more robust evidence base for our conclusions. Around 67% of children with ADHD exhibit deficits in WM, which is considered one of the neurocognitive endophenotypes of this neurodevelopmental condition (Ackermann et al., 2018). Neuroimaging research indicates that behavioral inhibition difficulties linked to ADHD generate deficits in the encoding and retention of verbal and visual data; in the infant population, it is related to a reduced ability to update information from previously acquired knowledge (Arjona Valladares et al., 2020; Breitling-Ziegler et al., 2020).

In ADHD, it is not only relevant to consider the associated neurocognitive deficits, but also the impact of this condition on relational processes; research has posited that infants with this nosology have problems in recognizing others; establishing empathy, sympathy, social communication, and recognition of authority figures (Hilton et al., 2020; Özbaran et al., 2018;

Storebø et al., 2019); have reduced capacity for reciprocity, and problems with emotional recognition of others (Şahin et al., 2018). These components have been defined as Social Skills (SS); they are mental systematizations underlying interaction involving the real social environment, reflecting different psychological faculties, and highlighting affect recognition (Miranda et al., 2017; Willis et al., 2019). SS enables the processing of explicit information from the environment, generating representations of self and others, resulting in mental states that modulate social behaviors; it has been reported that infants with a diagnosis of ADHD show deficits in SS related to the typically developing population (Villemonteix et al., 2017).

There is a vast scientific production that has been devoted to the analysis of WM and SS in ADHD (Shephard et al., 2019). Publications analyzing the association between these two psychic processes are reduced (Groves et al., 2020; Romani et al., 2018). Identifying this association can help mental health specialists formulate effective neuropsychological stimulation treatments that lead to progress in various contexts, prevent long-term complications, emotional, academic and social problems, as well as the development of an antisocial structure.

SS plays a significant role in problem-solving competencies, self-esteem, auto control and educative performance (Caballo et al., 2015). The formation of SS is shaped by several complex elements, including the environment, upbringing, neurocognitive processing, cultural context and heredity (Gómez-Tabares et al., 2021).

This study aims to analyze the capacity of WM as an explanatory element of SS in schoolchildren diagnosed with ADHD, through a Structural Equation Model (SEM). The research question posed was: Does WM have an effect on SS in school children diagnosed with ADHD?

SS was established as an endogenous variable and WM as an exogenous variable. The observable variables of SS were: interaction with authority figures, interaction with the opposite sex, embarrassment, assertive expression of annoyance/disgust/anger, interaction with strangers, and acting in public. The observable variables of the WM were: digit, letter/number, colour, word, and word/colour tests. The working hypothesis was defined as H0. WM (X) explains SS (Y) in schoolchildren with ADHD. It is represented in equation (1).

$$Y = bX + \varepsilon \qquad (1)$$

2. Methodology

Diverse epidemiological studies have demonstrated that ADHD is more frequent in males than in female children. Research shows higher ADHD prevalence in males, with gender ratios ranging from 2:1 to 3:1 in community studies, and up to 9:1 in clinical samples (De Rossi et al.,

2022). This higher incidence in males may be due to more frequent disruptive behaviors, increasing the likelihood of detection and referral for treatment (Mohammadi et al., 2021). Additionally, ADHD symptoms often manifest more prominently in school settings, where males tend to exhibit greater behavioral challenges compared to females, leading to more frequent diagnoses in this group. Therefore, this study focuses exclusively on the male child population.

2.1 Design

In this study, we used a quantitative approach, a cross-sectional study with an explanatory level and non-experimental design to analyze whether WM is an element that impacts SS in school children with a diagnosis of ADHD (Garcia Rincon et al., 2020).

2.2 Participants

A sample of n=250 males, the sampling was probabilistic. To calculate the sample size, the following formula was used:

$$\mathrm{n} = \frac{Z^2.p.q.N}{N.e^2 + Z^2.p.q}$$

Where: Z is the confidence level, N is the population size (N=718), p is the probability in favor (0.5), q is the probability against (0.5), e is the error of the estimate (0.05) and n is the sample size.

2.2.1 Selection criteria of the sample

Children with a diagnosis of ADHD issued by a specialized professional were included. The eligibility criteria are set out below.

Criteria for Inclusion of Participants: (1) Males aged between 9 and 12 years., (2) School-aged children, (3) Diagnosed with ADHD, (4) Evaluated in a neurological Center in Medellin, Colombia, (5) No comorbidities, (6) No intellectual disability. Criteria for Exclusion of Participants: (1) Presence of comorbidities, (2) Presence of intellectual disability, (3) Non-schooled children.

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During the study, the significant sample of 250 participants was maintained despite the dropout of 37 participants. Each dropout was replaced by another participant who met the inclusion criteria, thereby ensuring the integrity of the sample.

2.3 Instruments

To create the instructions and materials for the study, we followed a rigorous process to ensure clarity and participant comprehension. Each test includes its specific instructions, and the neuropsychology professionals conducting the evaluations are trained to explain and ensure the understanding of the male child participants.

CANSO- N24 (Caballo et al., 2016). The assessment allows the evaluation of social skills, social responses, or anxiety symptoms; it is a self-report questionnaire aimed at boys (males) aged 9 to 15 years. This is made up of 24 constructs, estimated on a Likert scale from 1 to 4, wherein a rating of 1 signifies minimal, 2 denotes slight, 3 indicates considerable and 4 represents significant. It encompasses six factors: interaction with authority figures, interaction with the opposite sex, embarrassment/ridicule, assertive expression of annoyance/disgust/anger, interaction with strangers, and acting in public. The overall questionnaire exhibits internal consistency with a Cronbach's alpha of 0.90, the Guttman reliability for its two halves is 0.94 and has content validity.

Wechsler Intelligence Scale (WISC-IV) (Wechsler, 2005). It assesses intellectual/neurocognitive functioning, was developed for ages 6 to 16 years and has 10 core tests and 5 additional tests. In the context of this study, the tests that assess WM (digits and letters/numbers) were used, these estimate the ability to record and retain data; letters/numbers also assess the ability to store and compose different types of data; digits measures succession skills, sorting, attention and cognitive flexibility of WM. The scoring of the applied tests includes the raw score, which is the total number of correct items. This is converted into a scaled score using WISC-IV normative tables that adjust scores based on the child's age. Scaled scores are interpreted with a mean of 10 and a standard deviation of 3; scores significantly above or below the mean may indicate strengths or weaknesses in working memory. The WISC-IV is a test with high content, construct, and concurrent validity, and demonstrated reliability with internal consistency coefficients typically above 0.90, test-retest reliability above 0.85, and inter-rater reliability also above 0.90 (Thompson et al., 2018).

STROOP. Colors and Words Test (Golden, 2020). This assessment stands out as a key tool in identifying neuropsychological disorders and brain lesions. Its usefulness lies in its ability to examine the phenomenon of interference, which is closely associated with inhibitory control processes. Specifically, it analyzes aspects of attention linked to WM (Lezak et al., 2004). The application of the instrument has a scope to all population groups, covers a broad spectrum of ages (6-85), and is provided individually; it consists of three different tasks. In the first, called state -Word- or P, the words RED/GREEN/BLUE are shown on a sheet of paper randomly arranged in black. The test taker must read the words aloud. In the next task, called state -Color- or C, sets of -XXXX- are shown, printed in blue, green, or red colors, and the task is to express their color. In the last task, called -Word/Color- or PC state, the identical words of task 1 are presented, but printed in the color of task 2, this generates inconsistency between the words and the colors of the printout. The score for each task is recorded separately. These scores are transformed using specific normative means and standard deviations: for Word (mean 79, SD 19), for Color (mean 53, SD 12), and for Word/Color (mean 31, SD 8). Each task is limited to 45 seconds, and the entire test, including instructions, takes approximately 5 minutes. Concurrent validity has been confirmed through correlations with other assessments of similar cognitive functions. The test has high test-retest reliability, with coefficients generally exceeding 0.70, demonstrating score consistency over time. Additionally, it shows internal consistency, with Cronbach's alpha coefficients typically above 0.80 (Emek Savaş et al., 2019).

In SEM, latent and observable variables are considered. Table 1 presents the description of the observable variables. Regarding the latent variables, two were considered (SS was the endogenous variable, and WM was the exogenous variable). The endogenous variable (SS) was measured with the CANSO-N24 instrument, and the exogenous variable (WM) was measured with subtests from the WISC-IV and the STROOP test.

Table 1. Characterization of observable variables

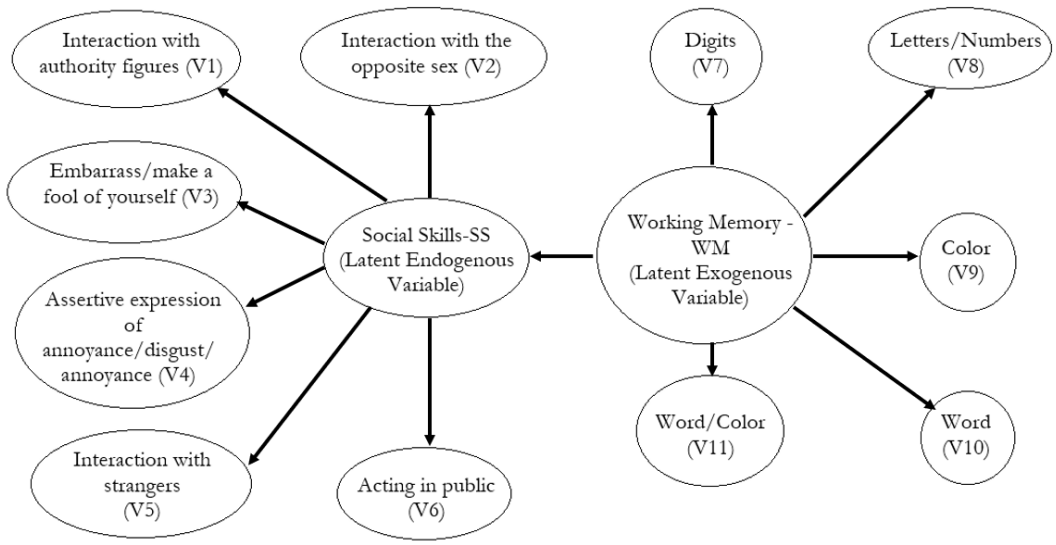
Observable Variables	Nomenclature	Description	Nature	Scale
Endogenous Variable (SS)	V1	Interaction with authority figures	Quantitative	Reason
	V2	Interaction with the opposite sex		
	V3	Embarrassing/ Making a fool of yourself		
	V4	Assertive expression of annoyance, displeasure or anger.		
	V5	Interaction with strangers		
	V6	Acting in public		
Exogenous Variable (WM)	V7	Digits		
	V8	Letters/Numbers		
	V9	Color		
	V10	Word		
	V11	Word/Color		

2.4 Data analysis

For the construction of the SEM, the free software for graphing and statistical analysis, Rcran 4.3.2, was used, which can be compiled and run on various operating systems (R Foundation for Statistical Computing, 2023). The following libraries were used: Lavaan, that is compatible with various latent variable models, encompassing SEM, confirmatory factor analysis, and latent growth curve models (Lavaan, 2023). Corrplot, provides a visual exploration tool for the correlation matrix, allowing automatic reordering of variables; this facilitates the detection of underlying patterns among variables (Corrplot, 2023). Haven imports external statistical formats into R (SPSS, Stata and SAS) (Haven, 2023). semPlot: allows for path diagramming and visual analysis of the output of various MEE packages(semPlot, 2023); the estimation plot was constructed with STATA 14 software (StataCorp, 2015). Diagram creates visual representations of simple graphs using a transition matrix, and provides tools for the creation of flowcharts, facilitates the visualization of different types of structures (Diagram, 2023).

This work constructed a structural regression model with an endogenous variable. It is assumed that WM positively predicts SS. Figure 1, presents the path diagram, this graphically illustrates the interrelationships between variables by arrows pointing to the directions of the influences, each arrow symbolizes a causal connection between the variables, which are known as "path" or "trajectory"; this scheme provides a visual tool that facilitates the understanding of the structure of the model by showing how the variables are linked to each other (Hair & Sarstedt, 2019). Table 2 describes the variables.

Figure 1. Path diagram



Note: V1-V11=Observed Variables

Table 2. Description of variables

Type of Variable	Nomenclature	Observable Variables
Endogenous	SS	= Embarrassment / making a fool of oneself + Interaction with authority figure + Interaction with opposite sex + Embarrassment/ridicule + Assertive expression of annoyance, displeasure or anger + Interaction with strangers + Acting in public
Exogenous	WM	= Digits + Keys + Color + Word + Word/color

2.5 Procedure

From a population of 718 children with ADHD, 250 were selected who met the established inclusion criteria according to the sample size calculation. The evaluations were conducted at a Neurological Center in Medellin, Colombia, by specialized professionals. The legal representatives/parents of the sample approved and signed the consent for the evaluation of the schoolchildren. It should be noted that the tests were administered individually and the average duration of each evaluation was approximately one hour per participant. The specialized professionals conducted a comprehensive neuropsychological evaluation and were not informed of the data that would be used in the present study. Participants completed a series of cognitive tests, not only those specific to the study. This approach was taken to prevent any bias in the participants' responses or the evaluators' behavior during the assessments.

The legal representatives/parents of the male children were thoroughly informed about the procedure, the risks, and the measures taken to ensure the privacy and confidentiality of the participant. Regarding the risks, they were informed that this research is considered minimal risk, in accordance with Article 11 of Resolution 008430 of 1993 by the Colombian Ministry of Health, as it involves the recording of data through common procedures consisting of diagnostic psychological evaluations. Additionally, it was assured that all the information collected would be treated with the utmost confidentiality and that the privacy of the participants would be safeguarded at all times.

3. Results

The SEM follows a series of detailed steps to ensure its validity and robustness. First, latent and observable variables are identified. In our study, the latent variables were SS as the endogenous variable WM as the exogenous variable, while the observable variables were measured through various subtests. Second, data collection and preparation are conducted. We used RCran 4.3.2 and several specialized libraries such as Lavaan, Corrplot, Haven, and semPlot for data analysis and visualization. Third, the theoretical model is specified by defining the relationships between latent and observable variables, represented in a path diagram (Figure 1). Fourth, the model is

estimated using maximum likelihood methods to obtain the coefficients of the specified relationships. Fifth, model fit is evaluated using statistics such as Chi-square(χ^2), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI), selected for their acceptance in the scientific literature and their ability to provide a comprehensive view of model fit. Finally, the model is interpreted and reported, ensuring that both fit values and the theoretical and practical implications of the results are considered.

This section first presents the demographic characterization of the sample used. Subsequently, the statistical results of the applied tests are shown. Then, the correlation matrix of the observed variables is presented, and finally, the results of SEM are provided.

The sample evaluated was N=250 children, male, living in the city of Medellín, Colombia. Age (Mean=10.6 years, SD=1.13), schooling level (Mean=4, SD=0.85) and socioeconomic level (Mean=3, SD=0.40). The children included in the sample are at the basic education level, according to the classification of the education system in various countries; this academic period is characterized by the evolution and reinforcing of literacy and numeracy abilities, as well as the promotion of social competencies and autonomy (Schneider, 2022). The sample reflected lower-middle socio-economic strata; globally, strata are determined by factors such as GDP per capita, access to education, quality of life and wealth distribution; high-income countries, with strong economies and high living standards, occupy the top; in contrast, there are middle- and low-income countries, characterized by greater economic and social disparities (Wani, 2019). Table 3 provides the sample's descriptive statistics.

Table 3. Summary of sample descriptive

Descriptive	Age	Schooling level	Socio-economic level
Me	11.0	4	3
$\bar{X}$	10.6	4	3
Mo	11	5	3
SD	1.13	0.85	0.40
S^2	1.28	0.73	0.16
R	[9.0 – 12.0]	[2 – 5]	[2 – 4]

Note: Me = Median, $\bar{X}$ = Mean, Mo = Mode, SD = Standard Deviation, S^2 = Variance, R = Range

Table 4 shows the descriptive statistics of the results of the instruments. In the RPDI column, the range of the direct score of each measurement test is presented; it is observed that the evaluated sample of schoolchildren with ADHD in SS presents greater difficulty in the direct expression of irritation, displeasure or anger and in the interaction with authority figures. The WM results indicate low performance in central executive control (Digits, Letters/Number), phonological loop (Color, Word) and visuospatial agenda (Word/Color).

Table 4. Descriptions of the application of the measuring instruments

Test	Nomenclature	Me	$\bar{X}$	Mo	SD	S^2	R	DSRM
CANSO- N24	SS							
Interaction with authority figures	V1	8	8.03	5	9.36	3.06	[4-15]	[4-16]
Interaction with the opposite sex	V2	11	10.16	16	20.43	4.52	[4-16]	[4-16]
Embarrass/make a fool of yourself	V3	10	10.50	10	10.21	3.19	[4-16]	[4-16]
Assertive expression of annoyance/disgust/annoyance	V4	7	7.54	4	9.17	3.02	[4-16]	[4-16]
Interaction with strangers	V5	8	7.6	8	4.83	2.19	[4-14]	[4-16]
Acting in public	V6	10	10.18	10	10.63	3.26	[4-16]	[4-16]
Wechsler Intelligence Scale (WISC-IV)	WM							
Digits	V7	11	11.2	8	8.23	2.87	[7-17]	[0-54]
Letters/Numbers	V8	7	7.29	6	7.95	2.81	[1-16]	[0-30]
STROOP. Colors and Words Test	WM							
Color	V9	47	49.36	50	175.82	13.26	[27-77]	[0-100]
Word	V10	71	68.96	60	220.29	14.84	[31-96]	[0-100]
Word/Color	V11	26	27.2	19	104.94	10.24	[13-54]	[0-100]

Note: SS=Social Skills (Endogenous Latent Variable), WM=Working Memory (Exogenous Latent Variable), V1-V11=Observed Variables, DSRM = Direct scoring range of the measurement instrument

Table 5 presents the correlation matrix of the observable variables, showing how the different pairs of variables analyzed are related. The highest correlation was found between variables V1 and V4 (0.626), i.e., in the sample of infants with ADHD analyzed, interaction with authority figures and assertive expressions of annoyance, displeasure or anger are positively and directly related. The lowest correlation was between variables V5 and V9 (-0.250), i.e., in schoolchildren assessed with ADHD, there is an inverse relationship between verbal processing and the relationship with strangers. Values close to zero were also identified, indicating no obvious relationship among the variables.

Table 5. Correlation matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	1										
V2	0.288	1									
V3	0.011	0.528	1								
V4	0.626	0.285	0.118	1							
V5	0.450	0.379	0.192	0.397	1						
V6	0.249	0.487	0.493	0.173	0.229	1					
V7	0.066	0.322	0.491	-0.080	0.265	0.302	1				
V8	-0.151	0.201	0.145	-0.005	0.019	-0.122	0.235	1			
V9	-0.111	-0.044	0.042	-0.092	-0.250	0.086	-0.142	0.142	1		
V10	-0.014	0.179	0.141	0.091	0.085	-0.047	0.218	0.294	0.323	1	
V11	0.072	0.067	0.089	0.069	0.027	0.114	0.160	0.086	0.207	0.517	1

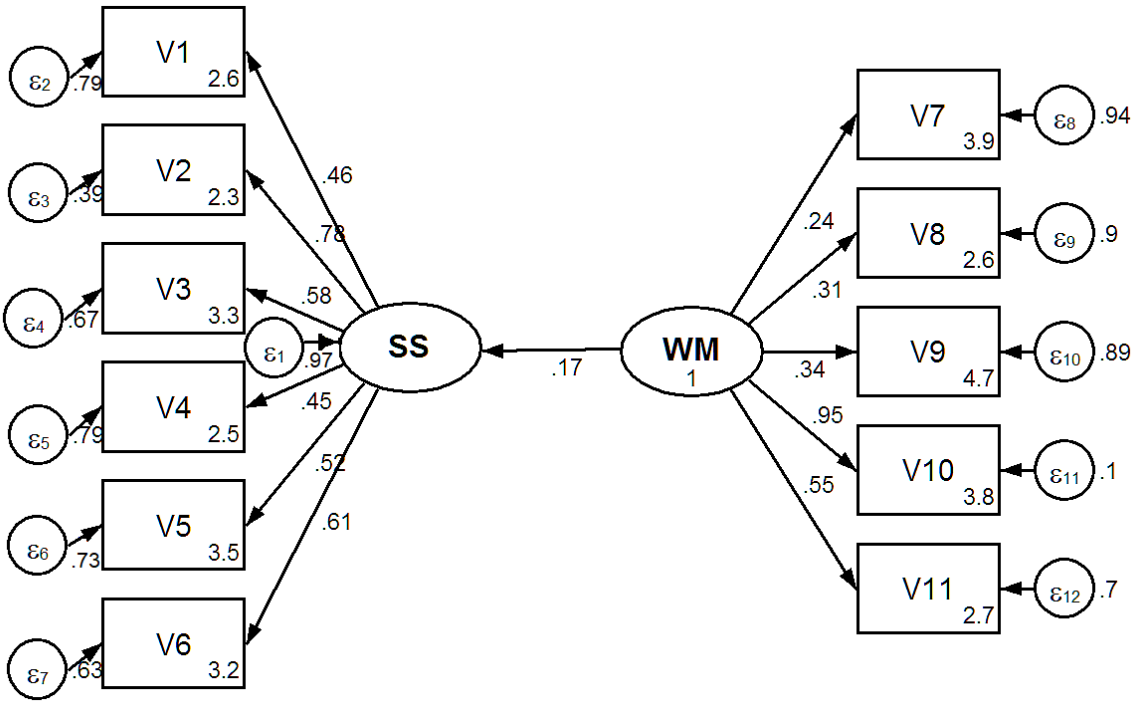
Note: V1= Interaction with authority figures, V2= Interaction with the opposite sex, V3= Embarrass/make a fool of yourself, V4= Assertive expression of annoyance/disgust/annoyance, V5= Interaction with strangers, V6=Acting in public, V7= Digits, V8= Letters/Numbers, V9= Color, V10= Word, V11= Word/Color.

Besides the high correlation between V1 and V4, other significant positive correlations are observed, such as between V2 and V3 (0.528) and between V3 and V6 (0.493). These relationships suggest that certain social behaviors, such as interaction with the opposite sex and acting in public, tend to co-occur in children with ADHD. Negative correlations, though less frequent, are important. For example, the negative correlation between V7 and V4 (-0.080) indicates that the ability to remember digits is inversely related to assertive expression of annoyance. Correlations close to zero, such as between V8 and V1 (-0.151), suggest that some cognitive abilities and social behaviors are not directly related. These correlations may have clinical implications, indicating areas where professionals can focus on specific interventions. For example, improving interaction with authority figures could positively affect assertive emotional expression.

In the results of our study, we used several model fit statistics to ensure the robustness and validity of our SEM. Specifically, we selected the Chi-square (χ^2), CFI and TLI due to their wide acceptance and use in the scientific literature for evaluating SEM models. The Chi-square allowed us to assess the overall discrepancy between the hypothesized model and the observed data. Although a significant Chi-square (χ^2) value suggests that the model doesn't perfectly fit the data, it is common to obtain significant values in complex models with large samples, like ours, hence the use of CFI and TLI. These indices compare the fitted model to a null model, providing a measure of incremental fit. CFI and TLI values close to or above 0.90 generally indicate a good fit. The selection of these statistics is based on their ability to provide a comprehensive view of model fit, considering both parsimony and data adequacy.

The estimation model is presented in Figure 2, it is evident that the observable variables (V1-V6) were reliable and valid measures of the latent variable (SS), supported by a medium to high significant factor loading ($\beta = 0.45 - 0.78$, $P(>|z|) < 0.001$). On the other hand, the observable variables (V7-V11) were not identified as reliable and valid measures of the latent variable (WM), as they obtained a low to high factor loading ($\beta = 0.24 - 0.95$, $P(>|z|) > 0.001$). Although the covariance between SS and WM was not significantly different from zero (0.17) with a $P(>|z|) = 0.379$, the chi-square indices (P-value $\chi^2 = 0.000$), CFI = 0.634 and TLI = 0.532, suggesting that the model appropriately captures the data.

Figure 2. Estimation model



Note: SS=Social Skills, WM=Working Memory, V1-V11=Observed Variables

Figure 2 presents the SEM estimation model used in this study. In the diagram, the ovals represent the latent variables, WM and SS. The rectangles represent the observable variables that are directly measured through the questionnaires and tests applied. The arrows indicate the causal relationships between the variables. The arrows from WM to SS show the influence that WM has on SS. The arrows from latent variables to observable variables represent the factor loadings, indicating how each observable variable contributes to measuring the corresponding latent variable. The SEM showed that the observable variables for SS and WM have significant factor loadings (β = 0.45 - 0.78, $P(>|z|) < 0.001$). The positive covariance between WM and SS was low (0.17) and not significant ($P(>|z|) = 0.379$), suggesting that WM is not the sole factor explaining SS.

4. Discussion

The findings of this study indicate that, while there is a positive relationship between WM and SS in children with ADHD, WM is not the sole explanatory factor for SS. The SEM revealed a low positive covariance (0.17) between WM and SS, with low significance ($P(>|z|) = 0.379$). These results suggest that multiple factors, including other mental processes, genetic, and environmental influences, contribute to the development of SS in children with ADHD. This is consistent with previous studies that have shown that SS development in children with

ADHD is influenced by a combination of executive functions, emotional regulation, and environmental factors (Cardillo et al., 2023; Kofler et al., 2019).

Our hypothesis posited that WM would significantly predict SS in children with ADHD, reflecting the fundamental role of cognitive processes in social behavior. While our results partially support this hypothesis, indicating a relationship between WM and SS, the low positive covariance and its lack of significance highlights the complexity of social skills development. These findings align with theoretical frameworks suggesting that SS are multifactorial, influenced by not only WM but also by a range of cognitive functions, emotional regulation capabilities, and environmental contexts (Groves et al., 2020; Lavigne et al., 2020). The presence of other contributing factors such as genetic predispositions and the quality of social interactions further complicates the direct influence of WM on SS (Al-Yagon et al., 2020; Storebø et al., 2019). Therefore, our results emphasize the need to consider a broader array of influences when addressing SS deficits in children with ADHD, consistent with integrative models of ADHD that account for diverse cognitive, emotional, and contextual elements (Bolfer et al., 2017; Maziero et al., 2023).

Studies report that ADHD generates difficulty in encoding social response cues and emotion recognition (Tajik-Parvinchi et al., 2021). Environmental demands become factors that impede the integration of different stimuli and emotional regulation (Tarle et al., 2021). The severity of behavioral symptoms is related to SS problems; research has addressed the issue of behavioral dysregulation in ADHD; children with this diagnosis generate conflicts in play with peers and experience elevated levels of parental rejection and strained relationships (Barnes et al., 2017).

Males are more commonly affected by ADHD compared to females (Mowlem et al., 2019); in this study, only males were contemplated. This research sought to analyze the capacity of WM as an explanatory element of SS in schoolchildren diagnosed with ADHD, through an SEM. The results indicate that WM is only one explanatory element of SS (Groves et al., 2020; Lavigne et al., 2020); cultural, environmental and genetic elements converge in these (Al-Yagon et al., 2020; Storebø et al., 2019). This justifies the reason why the value of the covariance between SS and WM was low (0.17). Due to deficits in the phonological loop, children with ADHD experience difficulties in retaining and processing verbal instructions in social contexts (Maziero et al., 2023; Rodríguez-Martínez et al., 2023). Deficits in the central executive system generate interference in efficiently coordinating social information from diverse sources (Drigas & Karyotaki, 2019; Friedman et al., 2022). ADHD results in difficulties in simultaneously integrating and processing different aspects of social interactions, such as verbal and nonverbal cues (Löytömäki et al., 2020). In interactions with authority figures, children with this nosology

face challenges in regulating behavior and show impulsivity and distractibility (Cibrian et al., 2020; Tarle et al., 2021).

Impulsivity interferes with the assertive expression of emotions by making it difficult to consider and carefully select words and actions (Matthys & Schutter, 2022); intense and rapid mood swings negatively impact coherent and controlled emotional responses (Blader, 2021). Deficits in sustained attention are another characteristic of ADHD, which hinders full participation in social interactions and limits opportunities to express oneself effectively (Bodalski et al., 2023).

ADHD involves insufficiencies in WM, mainly in the functions responsible for coordinating the cognitive resources responsible for attention that prioritize information processing (Nigg et al., 2018). Research evidence suggests that the attentional problems associated with ADHD compromise WM and the ability to execute the various actions of daily living (Irwin et al., 2021), causing this function to not respond adequately to instructions to identify and retrieve stimuli to act (Vadnais et al., 2018; Weigard & Huang-Pollock, 2017). The development of SS is related to the maturity of cognitive processes such as WM, which influences the processing of recent information (Bolfer et al., 2017); SS is involved in emotional expression and regulation (Groves et al., 2020).

These findings could have implications for depression. For instance, if SS and WM are low, this will reduce an individual's perceived control over their life, potentially leading to feelings of depression and low mood. Myles et al. (2020) found that low perceived control and low desire for control are associated with higher levels of depressive symptoms. Future research should explore how interventions aimed at improving WM and SS might enhance perceived control and reduce the risk of depression in this population.

5. Conclusions

A positive covariance (0.17) was found between WM and SS in schoolchildren with ADHD; however, it is emphasized that WM does not constitute the only neurocognitive determinant of SS in the context of ADHD, as the P(>|z|) of 0.379 indicates low significance. The need to consider other elements, such as additional mental processes, genetic, cultural and environmental influence, is emphasized for a more complete understanding of SS in ADHD.

The main limitation of this study was the absence of a control group raises the need for more robust research designs that allow for a more robust comparison and interpretation of the results. It's essential to consider that the study's sample solely comprised children, thereby constraining the broader applicability of the results to the entire child population. Moreover,

the specific insights garnered from this study cannot be extended to encompass girls with ADHD.

Ethical approval

On February 22, 2022, the Research Ethics Committee of the Luis Amigo Catholic University in Act No. 01, submitted for review the informed consent of the research project entitled: "Computerized training program of working memory in children diagnosed with Attention Deficit/Hyperactivity Disorder in Medellín, Colombia". The same was approved with file number 65136.

Informed Consent Statement

The informed consent complies with the requirements of Article 15 of Resolution No. 008423 of 1993, issued by the Ministry of Health, and according to Article 11 of the same, the project is classified in the category: "Research with minimal risk" since the behavior of the participants was not manipulated. The approval record 70625 for informed consent 48652.

Data Availability Statement

Upon a reasonable request, the researcher who corresponds with the study is ready to provide the data that was used and analyzed.

Conflict of interest statement

The authors confirm that there are no conflicts of interest, financial or personal, that could potentially influence the findings and interpretations presented in this research paper.

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Authors' Contribution

Catalina Quintero-López: Writing – original draft, Investigation, Data curation, Conceptualization. Victor Daniel Gil-Vera: Investigation, Data curation, Review & editing, Statistical analysis. Juliana Valencia Ochoa: Data recollection. Alejandra Herrera Vélez: Data evaluation.

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