The influence of cognitive profile in the problem-solving abilities of students with ASD

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Introduction

- Recent increase in the number of students with autism spectrum disorders (ASD) who attend general education classrooms (McDonald et al., 2019).
- Growing interest in studying the academic performance of these individuals, and in particular their mathematical performance
- In ASD individuals, cognitive deficits that could interfere with mathematical performance during the problem-solving process
- In ASD individuals, more rudimentary math problem-solving strategies like those based on drawing and counting persist
- We examine relationships between mathematical problem-solving performance (in terms of the strategies used and accuracy of responses) and the main cognitive domains associated with mathematical performance of children with and without ASD.

Objectives

- Study strategies used during the mathematical problem-solving process both in autistic and non-autistic students.
- Determine associations between the level of abstraction of the strategies used, and the main cognitive domains associated with mathematical performance, such as executive functions, verbal comprehension and social perception (affect recognition and Theory of Mind).

Methodology

- Participants. 26 autistic and 26 non-autistic children without intellectual disabilities, between 6 and 12 years old, matched by sex, age and school (grade and classroom).

Sociodemographic and Clinical Data and Mathematical Competence

	ASD (*N*=26)	non-ASD (*N*=26)	Statistics	*p*	Effect size
Sex (males)	23 (88.4%)	23 (88.4%)	$\chi^2(2) = 0.00$	1.000	$\Phi = 0.00$
Age (years)	9.35 *(2.06)*	9.41 *(1.96)*	t (50) = -0.10	.922	*d* = -0.03
Parental SES			$\chi^2(4) = 4.56$	.336	V = 0.30
V (High level)	5 (19.2%)	9 (34.6%)			
IV (High-middle level)	8 (30.8%)	8 (30.8%)			
III (Middle level)	8 (30.8%)	3 (11.5%)			
II (Low-middle level)	4 (15.4%)	3 (11.5%)			
I (Low level)	1 (3.8%)	3 (11.5%)			
Mathematical competence					
TEMA-3 score	54.00 *(13.15)*	62.81 *(10.19)*	*t* (50) = -2.70	.009**	*d* = -0.75
Mathematical age	7.56 *(1.10)*	8.38 *(0.93)*	*t* (50) = -2.89	.006**	*d* = -0.81
Intelligence					
WISC-FSIQ	89.88 (*11.78*)	102.00 (*10.98*)	*t* (50) = -3.84	<.001**	*d* = -1.06
Executive Functions					
Working memory	89.85 *(12.47)*	100.54 *(11.56)*	*t* (50) = -3.19	.002**	*d* = -0.89
Response set	7.62 *(3.44)*	8.71 *(3.04)*	*t* (50) = -1.09	.281	*d* = -0.34
Inhibition	6.62 *(3.31)*	9.31 *(3.80)*	*t* (50) = -2.72	.009**	*d* = -0.75
Verbal comprehension	89.81 (*19.29*)	104.96 (*11.84*)	*t* (50) = -3.41	.001**	*d* = -0.95
Social perception					
Affect recognition	7.50 *(3.34)*	9.92 *(1.94)*	*t* (50) = -3.20	.002**	*d* = -0.89
Theory of Mind	16.31 *(6.79)*	22.54 *(2.52)*	*U* = 126.50	<.001**	η^2 = 0.29

- Mathematical problem solving strategies (example for a 4x8 problem):

(1) incorrect strategies (e.g. perfomrs a sum 4+8)
(2) direct modeling with counting (e.g. draws four groups with eight objects each, and counts everything);
(3) counting strategies (e.g. repeated addition 8 + 8 + 8 + 8); and
(4) number facts (solves the multiplication 4x8).

Results

MATH PERFORMANCE

Mathematical Problem Solving in ASD and non-ASD Students

	ASD (*N*=26)		non-ASD (*N*=26)		Statistics	*p*	Effect size
MPI median score	1.98 (*1.34*), range:1 – 4		2.35 (*1.38*), range: 1 – 4		*t* (50) = 0.44	.339	*d* = -0.27
Accuracy (out of 1)	0.35 (*0.38*), range:0 – 1		0.50 (*0.28*), range: 0.13 – 1		*t* (50) = -1.62	.112	*d* = -0.45
Level of accuracy	Observed	Expected	Observed	Expected			
0-25%	15 (57%)	10.5 (40.4%)	6 (23%)	10.5 (40.4%)	*Fisher´s*=8.57	.034*	*V* = 0.41
26-50%	3 (11.5%)	7 (26.9%)	11 (42.3%)	7 (26.9%)			
51-75%	3 (11.5%)	3.5(13.5%)	4 (15.4%)	3.5 (13.5%)			
76-100%	5 (19.2%)	5 (19.2%)	5 (19.2%)	5 (19.2%)			

Note. ASD: Autism Spectrum Disorder without intellectual disability; d: Cohen´s D; MPI: Mathematical Problem Instrument; SD: Standard deviation; V= Cramer´s V.

Results

COGNITIVE ABILITIES AND MATH PERFORMANCE

Neurocognitive Scores Based on the Accuracy Rate Groups in ASD and non-ASD Students

	ASD (*N*=26)				Non-ASD (*N*=26)			
	≤25% (*n*=15)	>25% (*n*=11)			≤25% (*n*=6)	>25% (*n*=20)		
Neurocognitive variables	Mean (*SE*)	Mean (*SE*)	*F* (1, 24); *p*	Effect size	Mean (*SE*)	Mean (SE)	*F* (1, 24); *p*	Effect size
Executive functions								
Working memory	86.85 (*3.48*)	93.93 (*4.36*)	*F*=1.12; *p*=.302	η^2= 0.05	99.53 (*5.40*)	100.84 (*2.63*)	*F*=0.04; *p*=.841	η^2= 0.00
Response set	6.28 (*1.27*)	8.84 (*1.20*)	*F*=1.522; *p*=.235	η^2= 0.09	10.05 (*1.72*)	8.63 (*0.63*)	*F*=0.68; *p*=.423	η^2= 0.04
Inhibition	4.82 (*1.06*)	9.07 (*1.33*)	*F*=4.34; *p*=.050*	η^2= 0.17	10.78 (*1.67*)	8.86 (*0.81*)	*F*=0.93; *p*=.346	η^2=0.04
Verbal comprehension	83.81 (*3.32*)	97.98 (*4.16*)	F=4.94; *p*=.037*	η^2= 0.19	105.47 (*4.57*)	104.81 (*2.23*)	*F*=0.01; *p*=.905	η^2=0.00
Social perception								
Affect recognition	7.78 (*1.15*)	7.12 (*1.44*)	*F*=0.08; *p*=.706	η^2=0.00	10.09 (*0.95*)	9.87 (*0.46*)	*F*=0.04; *p*=.844	η^2=0.00
Theory of Mind	13.50 (*1.54*)	20.13 (*1.92*)	*F*=5.08; *p*=.035*	η^2= 0.20	23.06 (*0.97*)	22.38 (*0.47*)	*F*=0.34; *p*=.561	η^2= 0.02

Note. ASD: Autism Spectrum Disorder without intellectual disability; SE: Standard Error; η^2= Partial eta squared effect size
*: $p \leq .05$

- Among ASD students, lower level of abstraction of strategy by poorer performing ASD students (< 25% correct responses) with respect to the rest of the ASD group.
- In the non-ASD group, no differences in the strategy used.
- Positive correlation between the level of abstraction of the strategy used and three cognitive variables - inhibition, cognitive flexibility and ToM - in the whole group of ASD children, not found in the non-ASD group

Discussion

- Higher proportion of subjects with ASD (57%) compared to subjects without ASD (23%) in the group of poorer performers (≤ 25% correct answers).
- In the groups with the highest performance (success rate > 50% correct responses), there were no differences in the proportion of ASD compared to the non-ASD subjects.
- Poorer performing students with ASD used less elaborate strategies than the rest of ASD students
- positive correlation between the level of abstraction of the strategy used and three cognitive variables - inhibition, cognitive flexibility and theory of mind (ToM) - in the group of subjects with ASD, but not in the non-ASD group.
- it could be hypothesized that the use of simplistic strategies to solve mathematical problems by the population with ASD is indicative of cognitive deficits in these functions.
- This could help to identify the subgroup of students with ASD with the most mathematical difficulties.
- ASD students who exhibited poorer mathematical performance (i.e., ≤ 25% of correct responses) were comparatively impaired in terms of inhibition, theory of mind and verbal comprehension.

Conclusions

- Our results help understanding mathematical problem-solving difficulties in students with ASD.
- direct implications on the design of educational interventions in subjects with ASD and mathematical difficulties.
- Interventions should consider stimulating the cognitive functions involved in mathematical problem solving that are more affected in ASD population (cognitive flexibility, inhibition, theory of mind and verbal comprehension)
- Some methodologies Schema Based Instruction (SBI) or the Conceptual Model-Based Problem Solving (COMPS) approach have been successfully adapted to ASD students' characteristics improving their ability to solve mathematical problems (Bruno et al., 2021; García Moya et al., in press; Polo-Blanco et al., 2021, 2022))

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Project web: https://matematicasyautismo.unican.es/

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