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Joint Attention Ability and the Neurocognitive functioning in children with Autism Spectrum Disorders

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Abstract

Introduction: Autism spectrum disorders (ASD) have neurobiological origins but the exact nature of these brain dysfunctions has not been yet fully elucidated. Children with autism have difficulties in processing social and emotional stimuli, imitating body movements or interpreting relational gestures. These difficulties suggest as candidate factors related to autistic symptomatology, a specialised brain system involved in the mechanisms of social cognition, consisting in the medial temporal lobe (MTL) and the ventromedial prefrontal cortex (VMPFC).
Objectives: Our research examines whether young children with autism are impaired on neuropsychological tasks and also if the performance on such neurocognitive tasks can be correlated with joint attention ability (JAT).
Methods: Three groups of children – with autism, with intellectual disability and with typical development, matched according to the mental age (calculated with the Fairview development scale, Giampiccolo & Boroskin, 1974) were administered neurocognitive and joint attention tests and procedures.
Results: The results showed that only the MTL-VMPFC task performances were strongly correlated with the JAT behavior, while the dorsolateral prefrontal (DLPFC) ones were not.
Conclusion: Our findings suggest that the VMPFC is involved in the development of JAT mechanisms. We found no correlation between the performance in tasks related to JAT behavior and the DLPFC factor. This means that autism is not associated, at least at young ages, with a unique pattern of poor executive functioning, so this dimension cannot be used as an indicator for the early diagnosis of autism.

Key words: autism, neurocognitive functioning, neuropsychological evaluation, joint attention, structural equations model

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1. Introduction

Autism still features a wide range of unknown aspects, even after more than 75 years since Kanner (1943) first described it. Scientists are still far from reaching a consensus concerning its causes, the precise origins of cognitive and other deficiencies, as well as the efficient therapeutic methods.

A particularly important indicator in diagnosing autism is the deficiency in JAT (Saleh & Adel, 2017). JAT refers to a socio-communicative, pre-linguistic ability, accomplished by shared gestures and mutual monitoring of the attention given to an object or event (Adamson, Bakeman & Deckner, 2005; Nyström, et al., 2019). The deficit in JAT development is one of autism's first symptoms, identified even before the age of one (Bottema-Beutel et al., 2014). As opposed to children with intellectual disability (ID) or language delays, only autistic children have JAT deficits (Charman, 2003; Landry and Loveland, 1998), this being a discrimination indicator of 80-90% between children with autism and those with other developmental disorders (Lawton & Kasari, 2011).

JAT deficit is an early marker of dysfunctions related to social motivation, typical for autism (Mundy, 2017). Moreover, JAT offers the ground for shared experience, which is extremely important in acquiring language, vocabulary being assimilated during JAT episodes (Morales-Hidalgo et al., 2018). Furthermore, this ability is related to the "Theory of mind" and to the pretend play – two socio-cognitive abilities, which develop later on, and which are dysfunctional in autistic children (Rosello et al., 2020). Research suggests a strong connection between JAT and neurocognitive abilities. Also, there is clear evidence of the existence of a specialised brain system for processing social stimuli which is comprised of MTL and VMPC (Dawson et al., 2002; Dichter et al., 2010; Murphy et al., 2017; Lau, Leung & Zhang, 2020). In this context, we organised our research as a replication and adaptation of the study realised by Dawson et al., (2002) within groups of Romanian children with ASD, intellectual disability (ID) and typical development (TD). We wanted to find out whether such children have dysfunctions in the MTL-VMPFC and DLPFC circuits and whether the tasks performance targeting these circuits correlates with JAT. Our methodology is based on the discovery of Dawson et all., (1998) and Koscik et al., (2012) that neurocognitive tasks such as DNMS and object discrimination reversal are mediated by both MTL and VMPFC circuits. Since Dawson's study, these relationships were also investigated by other researchers such as Spalding et al., (2018); Monk et al., (2010); Abbott et al., (2016); Lau, Leung & Zhang, (2020) and their results showed a consistent and strong connection between these circuits, which may provide an early insight into the effects of autism on cognitive and social functioning.

2. Materials and Methods

2.1. **The objective** of our study was to assess the neurocognitive functioning of children with autism through specific tasks (neuropsychological tasks for the MTL-VMPFC and DLPFC circuits), as well as to analyse the possible correlation between the performance of subjects in such tasks and JAT.

2.2. **Subjects**

Three groups of children were involved in this research: (1) autism: 32 children (23 boys and 9 girls), aged 34 - 52 months, (2) ID: 40 children (27 boys and 13 girls), aged 33 - 57 months and (3) TD: 34 (22 boys and 12 girls), aged 18 - 40 months. The three groups were balanced in terms of mental age using the Fairview development scale (Giampiccolo & Boroskin, 1974). The children with autism and ID were selected from "Hans Spalinger" Therapy Centers in Cluj-Napoca and Simeria and the children with TD were selected from random families known to the researcher and from the Waldorf kindergarten, Cluj-Napoca. Table 1 presents the demographic characteristics of the participants, such as gender and mental/chronological age.

Table 1

General and demographic information about the participants

Group	Number	Chronological age (months)			Mental age (months)		
	Boys/Girls	Minim	Maxim	Mean (SD)	Minim	Maxim	Mean (SD)
Autism	32. 23/9	34	52	43.5 (4.3)	11.8	46.8	25.2 (8.8)
Intellectual disability	40. 27/13	33	57	44.8 (5.3)	12.3	42.8	27.6 (8.2)
Typical development	34. 22/12	18	40	27.1 (8.9)	13.5	45.5	28.4 (9.1)

2.3. The context of the research

The evaluation of the children took place in the psychology office and was performed by two therapists, one interacting with the child during the tasks and the other being the observer who monitored the sessions and rated the answers. All the sessions were filmed for later analysis.

2.4. The evaluation of the cases

Every child with autism involved in this research went through a complex assessment procedure. We collected information from the activities performed in the therapeutic center but also from the residential care or family settings.

Global evaluation: a plenary assessment of autism cases was initially carried out aiming to collect as much information as possible, through various means: "Childhood Autism Assessment Scale" (Schopler et al., 1988); "Checklist of Behaviors and Skills for Children showing Autistic Features" (Aarons & Gittens, 1998), direct observation of the child, analysis of video sequences in various contexts, several variants of the test of false beliefs "Theory of mind" (Perner, Frith, Leslie & Leekam, 1989), studying the individual records of the cases, analysing behavioral products such as drawings, crafts etc. Children with ID were also assessed with the scales mentioned above in order to eliminate the possibility of an ASD diagnosis.

Neuropsychological evaluation: this evaluation of all children (with autism, with ID and with TD) took place during 5 sessions. The rewards given to the children for their involvement in the tests consisted in favorite toys, activities or candy. Neuropsychological tasks for the MTL-VMPFC circuit:

DNMS task: is based on the paradigm described by Dawson et al. (2002). Two versions of the DNMS task were administered. In the first version we used real objects, while in the second version we used laminated picture cards to cover the boxes. The dependent variables considered were: the percentage of successful tests of the child and the number of errors made in tasks. These two variants of the task were coded as DNMS – object and DNMS – picture.

The task of reversing object discrimination: the child must learn which of the two objects presented to them repeatedly is associated with the reward (in relation to the location of the object). After the child shows an understanding of the association and chooses the correct object five times in a row, the reversal occurs. The dependent variables for this task are the percentage of the child's successful attempts, the total number of errors per criterion and the total number of consecutive errors.

Neuropsychological tasks for the DLPFC circuit:

Task A not B: the child and the therapist are sitting at the table, face to face. Two identical blue cups are placed on the table, left and right, at equal distances from the child's position. Under the child's gaze, the experimenter places a reward under one of the two cups (right or left, randomly). Another person lowers a white panel in front of the child, blocking the view of the cups for 5 seconds. The panel is then raised and the child is stimulated to seek the reward (candy). If he indicates correctly, he receives it, if not, the experimenter shows the child the reward in the correct location but he does not receive it. After two reversals of the reward position followed by two successful attempts of the child, the time the cups are hidden by the panel is increased from 5 to 12 seconds. Sessions are continued with this 12-second hiding time until two more reversals of the reward position are made followed by two successful attempts. The dependent variables are the percentage of the child's correct response to tasks with a 5-second hiding time, the percentage of correct reversals at the 5-second hiding time, the percentage of the correct response at 12-second hiding time, and the percentage of correct reversals at 12-second intervals.

Task A not B with invisible replacement. This task is more complex than the previous one. The dependent variables in this phase are: the percentage of the child's correct answer and the percentage of inversions in which the child answered correctly.

Spatial reversal task: it is similar to task A not B because it requires spatial memory to find the hidden reward. This procedure is based on the paradigm developed by Kaufman, Leckman and Ort (1989). The dependent variables considered were: the percentage of the child's successful attempts and the percentage of inversions to which the child responded correctly.

Neuropsychological tasks for JAT:

Butterworth evaluation: it is based on a method developed by Butterworth and Jarret (1991), in order to analyse the JAT abilities of the preschool and young school children. The dependent variable in this case is the percentage of attempts in which the child fails in the test.

Unstructured assessment of JAT (Loveland & Landry, 1986): the purpose of this analysis was to measure the child's ability to respond correctly to protodeclarative behaviors initiated by the therapist and to assess the child's JAT behaviors (pointing, commenting, coordinating and sustaining JAT gestures etc.) intentionally produced by them, without guidance from the adult. This stage was the pre-intervention evaluation phase, focused specifically on the JAT field. Each child benefited from 10 JAT opportunities given by the therapist, the answers followed and rated being the following: (1) response to the appearance of an object (rated as correct if the child manipulated the new object presented by the therapist for at least 5 seconds, (2) watching/pointing (considered correct if the child looked in the direction of the therapist), (3) coordinating the alternation of gaze (correct answer – the child shifts the gaze between his toy and the experimenter for at least 10 seconds) and (4) protodeclarative pointing (correct answer – the child points spontaneously at an object or light source in the room and holds it for at least 10 seconds).

The scores are in the range 0 – 2. A score of 0 indicates the child's success in the task, a score of 1 indicates that verbal guidance was needed and a score of 2 indicates the child's inability to pay attention to the task.

3. Results

The results obtained by the subjects were recorded and processed using the SPSS 23 statistical program (IBM, 2015). The additional processing aimed at detecting the complex relationship between JAT mechanism and the neurocognitive circuits was performed using EQS 6 software (Bentler, 2006).

We first analysed the differences between the groups on the dimension of JAT. In this way, a multivariate analysis of variance (MANOVA) was performed for the three ways of assessing the JAT behavior used in this study (Butterworth Assessment, Landry Assessment, Loveland – JAT response and Landry Assessment, Loveland – JAT initiation). The group of children with autism presents, as we expected, a deficit in the JAT, compared to the other groups ($F = 18.22$, $p < 0.01$) and these significant deficits in children with autism are present in each of the three dimensions of JAT behavior. The performance of the children with ID and of those with a TD does not differ significantly on these dimensions of JAT behaviors. This finding shows, once again, the existence of a unique pattern of dysfunction in terms of JAT behavior in children with autism (see Table 2).

We further analyzed the differences between the groups studied in terms of neurocognitive functioning. To test the hypothesis that autistic subjects show much lower task performance for the MTL-VMPFC circuit than children with ID and those with a TD of the same mental age, a series of univariate analysis of variance (ANOVA) were performed. We analysed the percentage of correct answers of the subjects and the number of errors of the subjects to the criterion. Table 3 presents the descriptive statistics for the dependent variables considered in this situation.

Table 2

Joint attention behavior in children with autism, intellectual disability and typical development

Joint attention evaluation	AUTISM		INTELLECTUAL DISABILITY		TIPICALLY DEVELOPED		
	Mean	SD	Mean	SD	Mean	SD	Sign. P
Butterworth JAT	0.53	0.37	0.27	0.31	0.11	0.18	< 0.01
Landry/Loveland – initiation JAT	1.08	0.75	0.12	0.33	0.05	0.23	<0.01
Landry/Loveland – response JAT	0.85	0.82	0.24	0.55	0.05	0.23	<0.01

Table 3

Neurocognitive performance of the children involved in the research

	AUTISM group		INTELLECTUAL DISABILITY		TYPICAL DEVELOPMENT		
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	signification p
MTL-VMPFC circuit							
Swap of object discrimination							
Correct answer %	0.66	0.42	0.63	0.41	0.57	0.46	0.58
Number of errors/criteria	9.88	4.44	12.97	6.18	11.50	4.65	0.02
Number of recurrent errors	3.09	3.16	4.71	4.31	3.13	2.60	0.07
DNMS – object							
Correct answer %	0.68	0.22	0.74	0.23	0.75	0.19	0.24
Number of errors/criteria	4.65	3.85	3.68	3.95	3.74	3.48	0.34
DNMS – picture							
Correct answer %	0.64	0.23	0.63	0.22	0.68	0.19	0.55
Number of errors/criteria	4.68	2.80	4.47	2.65	3.97	2.31	0.42
DLPFC circuit							
A not B							
Correct answer % (5s)	0.86	0.16	0.85	0.18	0.81	0.17	0.42
Correct swapping % (5s)	0.73	0.33	0.76	0.34	0.69	0.34	0.70
Correct answer % (12s)	0.77	0.18	0.73	0.22	0.71	0.24	0.32
Correct swapping % (12s)	0.55	0.39	0.51	0.34	0.47	0.37	0.62
A not B with invisible placement							
Correct answer %	0.66	0.21	0.68	0.20	0.66	0.15	0.89
Correct swapping %	0.38	0.34	0.55	0.39	0.43	0.35	0.10
Spatial swap							
Correct answer %	0.66	0.13	0.61	0.14	0.64	0.13	0.28
Correct swapping %	0.03	0.10	0.08	0.22	0.06	0.19	0.42

In order to see the relationship between neurocognitive functioning and JAT behavior, the modeling procedure in structural equations was used to test the hypothesis that performance in tasks targeting the MTL-VMPFC circuit would be more strongly correlated with the ability of JAT of children with autism than performance in tasks targeting the DLPFC circuit. The spatial reversal task was not introduced in this model due to the substantial floor effect that the subjects showed in this case (90% of the subjects obtained a minimum score which suggests that the task was too difficult for the age of the children involved in the study). The latent factors for neurocognitive performance were defined from the other variables involved as follows: (1) MTL-VMPFC factor: % of correct answer for the task of reversing the object discrimination, for DNMS – object and DNMS – picture; (2) DLPFC factor: % of correct answer for A not B delay 5 seconds, A not B delay 12 seconds and A not B with invisible placement; (3) deficit factor in JAT: Butterworth – % of wrong answer, Landry/Loveland – response to JAT and Landry/Loveland – JAT initiation. For this statistical analysis, we used the EQS 6 program (Bentler, 2006) which permits covariance matrices. Table 4 shows the correlations between the variables in the structural equation model.

Table 4

The correlations between the variables involved in the structural model

		Butterworth	LL init	LL answ	Ob discr invers	DNMS pic	DNMS obj	AnotB 5sec	AnotB 12 sec	AnotB invis	FW
Butter worth	Pearson correl										
	N										
LL initiation	Pearson correl	.47									
	N	32									
LL answer	Pearson correl	.53	.40								
	N	32	32								
Ob discr invers	Pearson correl	-.41	-.39	-.27							
	N	32	32	32							
DNMS pic	Pearson correl	-.37	-.52	-.37	.45						
	N	32	32	32	32						
DNMS obj	Pearson correl	-.22	-.29	-.32	.31	.45					
	N	32	32	32	32	32					
AnotB 5sec	Pearson correl	-.10	.05	-.08	-.08	.08	.15				
	N	32	32	32	32	32	32				
AnotB 12 sec	Pearson correl	.13	.02	-.22	-.06	.22	.15	.50			
	N	32	32	32	32	32	32	32			
AnotB invis	Pearson correl	-.10	-.30	.05	.08	.31	.03	.295	.21		
	N	32	32	32	32	32	32	32	32		
Fairview (FW)	Pearson correl	-.71	-.52	-.545	.44	.44	.35	.03	.05	.25	
	N	32	32	32	32	32	32	32	32	32	

The two neurocognitive factors (MTL-VMPFC and DLPFC) were integrated in a confirmatory analysis model. This allows the calculation of the significance test on the neuropsychological indicators included in the two factors. The covariance between the two neurocognitive factors is achieved and we further analysed the degree to which each factor manifests variability over JAT (Figure 1). The correlation between MTL-VMPFC factor and JAT is negative (-.204; z = 3.58, p <0.01) while the correlation between DLPFC factor and JAT is almost zero (0.026; z = 0.55, p *<0.01)*. This means that superior performance on MTL-VMPFC circuit tasks correlates with low scores on the JAT deficit factor while the correlation between the DLPFC factor and JAT is insignificant (no correlation).

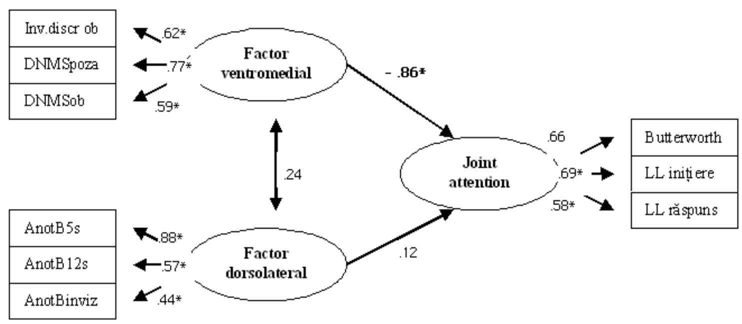

Figure 1: **Structural model of the relationship between JAT and neurocognitive factors.**

Furthermore, we introduced mental age as a variable in the model in order to test the specificity of the relationship between MTL-VMPFC circuit functioning and JAT (Figure 2). The contribution of the MTL-VMPFC factor is preserved (-.41*) in this case as well, highlighting the fact that the relationship between this factor and JAT is significant, while there is no correlation between JAT and DLPFC. Moreover, the correlation between the MTL-VMPFC factor and JAT remains significant even when mental age is added as a variable in the structural equation model, which highlights the specific, unique relationship between these two coordinates. The correlation between the variable mental age and JAT is, in this case, higher (-.59*) than that of each of the two neurocognitive factors (MTL-VMPFC and DLPFC).

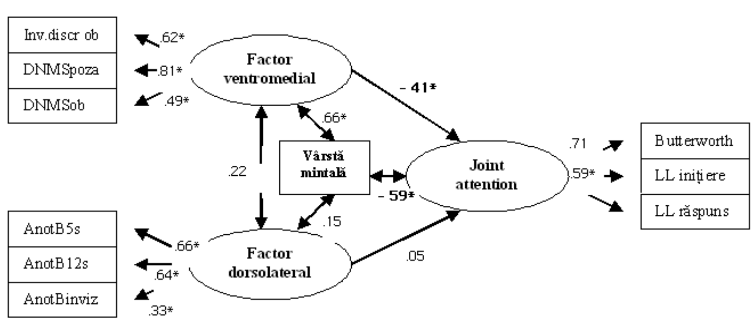

Figure 2: **Structural model of the relationship between JAT, neurocognitive functioning and mental age.**

4. Discussions

Our study aimed to investigate the performance in neurocognitive tasks by comparing three groups of children: with autism, with ID and with TD. We also wanted to see how this performance correlates with JAD development. Therefore, we used tests for MTL-VMPFC and DLPFC circuits as well as for JAT mechanisms. Our results show similar performance of all children in tasks assessing executive functions. Children with autism and those with ID show deficiencies in executive functions, but autism is not associated, at this early age, with a specific dysfunctional pattern. Executive functions mature later, during the first school years, so deficits related to executive functions cannot represent an early marker of ASD.

This study also investigated the way in which MTL-VMPFC and DLPFC circuits correlate with JAT development. Firstly, we must say that children with autism present a specific pattern of JAT deficiency, this being a pivotal indicator of autism, which enables the diagnosis before the age of one. Our study revealed the fact that the performance of children with autism in tasks related to the MTL-VMPFC circuit significantly correlates with JAT ability, while the performance in tasks related to the DLPFC circuit has no relation with JAT ability. This result was maintained when the subjects` mental age was introduced in the structural equations model in order to control the effect of this variable.

This is in accordance with the results found by Monk et al., (2010); Watanabe et al., (2012); Abbott et al., (2016); Spalding et al., (2018); Lau et al., (2020) which show the consistent and strong connectivity of autism with the structural and functional organisation of the brain in the early critical period of development. Moreover, these connections are involved in the entire communication development process, also having implications on higher-order cognitive processes and complex social functions.

4.1 Limitations

There were situations when the evaluation of the children was difficult and not standardised and this could lead to variations in the data collected. This happened because in some cases, part of the global assessment was based on the parents' and tutors' evaluations, which might lead to data distortions. The limited number of the participants in the study could also represent a weakness of the research.

5. Conclusions

Studies have shown that ASD has neurobiological origins (Tordjman et al., 2015) but the exact nature of these brain dysfunctions have not yet been fully elucidated. It is clear that people with autism have deficits in processing social and emotional stimuli (Mazza et al., 2017). In these circumstances, our study found that deficits in executive functions does not manifest at such a young age. In fact, the executive functions need maturation of prefrontal lobes which happens in the first school years. We also analysed how JAT in autism is related to the dysfunctions at the level of the MTL-VMPFC. Setting up a JAT development program will certainly help children with autism make progress in language skills and social interaction (Mundy, 2017). Thus, the role of executive functions in JAT is highlighted, which can be very helpful in developing therapeutic intervention plans. Such interventions can aim learning the relation between stimuli and reward, differentiation between social and non-social stimuli, motivation for behavior, setting and adjusting own expectations regarding a situation or interaction, anticipating consequences, focusing and maintaining focus in tasks. All these are mediated through the MTL-VMPFC circuit, so the development of these abilities can be monitored through tests specific for this circuit, like the tests used in this study.

Another contribution of this study, by confirming the relation between the MTL-VMPFC circuit and JAT, is the understanding that the increase in task performance related to this circuit will have a positive impact on JAT development, which, in turn, leads to the social, emotional and linguistic development of children with autism.

Future directions of research could analyse the relationship between the performance on tasks targeting the MTL-VMPFC and the ability of JAT or other social skills in the general population. Another important question is whether those neurocognitive dysfunctions, especially the ones involving the DLPFC circuit will show up at older ages of the persons with autism. We would recommend a longitudinal study of the cases in order to assess the developmental progression of the JAT mechanisms and of the executive functions and/or disfunctions.

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Conflict of interests
The author declares no conflict of interests.

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