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Executive functioning in autism spectrum disorders: a case-control study in preschool children.

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Abstract

Background: Autism spectrum disorders (ASD) are neurobehavioral and developmental conditions that include impairments in a triad of behavioral domains: social development, communication and repetitive behavior/obsessive interests. This case-control study aims to assess executive functioning in ASD preschoolers.

Methods: A sample of 50 children participated in the study (24 males and 26 females; age ranged between 2.7 and 3.5 years). The study sample was subdivided into two groups: 25 ASD children and 25 typically developing children as a control group. All participants were administered the BRIEF-P test to assess executive functioning.

Results: The two groups were counterbalanced for age and gender. Comparison analysis between the two groups revealed significantly higher scores in ASD children in two subscales of BRIEF-P: inhibition and shifting.

Conclusion: These data evidenced significant impairments in several dimensions of executive functions in ASD children. Detecting these deficits at a very early stage of development could therefore have a great impact on clinical practice.

Keywords: Autism spectrum disorders, Pre-school children, BRIEF-P, Executive functions.

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Introduction

Planning, behavior modulating and monitoring, behavioral and cognitive flexibility are complex abilities known as "executive functions". Functions that allow to voluntarily respond adaptively to complex or non-habitual conditions in which the automated response schemes are not appropriate or sufficient to achieve the goal [1]. When the task is familiar or simple, "automatic" action schemes may be sufficient. When the task requires choices, complex analyses, "automatic responses" are not sufficient but more "controlled" behavior requiring higher "attention" become necessary [1].

Executive functions, therefore, configure a set of abilities flexibly integrated each other in relation to the nature and complexity of the task and that 'make a person capable of successfully implementing independent, finalized and functional behaviors' [2].

The associative areas of the frontal lobe, strongly connected with multiple cortical and subcortical structures, subtend the highest executive functions [3]. These appear to be crucial both for the overall repertoire of finalized behaviors and for the cognitive productivity, especially for tasks requiring higher attention, memory and problem solving [4]. Moreover, these are crucial functions in the regulation of cognitive processes of "lower level" as well as in the modulation of the finalized behavior and in the processes of adaptation to the environment [5]. They also represent an essential prerequisite for the autonomous management of daily life, especially in new, complex or poorly structured situations. Functional or instrumental activities require executive skills, such as volition, planning, monitoring. Executive functions, therefore, represent prerequisite abilities supporting one's independence and autonomy in everyday life and act as an orchestra conductor that connects the various components of the cognitive system (attention, perception, memory, language) and favors their expression to the best of their potentiality [6-8].

According to the triad of impairments model, Autistic Spectrum Disorders (ASD) may be considered as a complex developmental condition characterized by impairment in a triad of behavioral domains: social development, communication

and repetitive behavior/obsessive interests [9]. Children with autism spectrum show strong repetitive behavior, a high desire for routines and a 'need for sameness'. Executive dysfunction theory assumes that such persevering or inability to shift attention in autism disorders may express a frontal lobe dysfunction [10]. The ASD repetitive behavior, the obsession with technical systems or inanimate events should be supported by an executive dysfunction compromising the shifting from one mental set to another (set-shifting), the control of a dominant response (inhibitory control), and the maintenance of information (working memory). The integrity of executive functionality, in the developmental age, can be considered predictive of many of the future positive cognitive and socio-emotional outcomes later in life [11].

ASD is multi-factorial and linked to a genetic predisposition triggered by environmental factors, both during embryonic development both in the first years of life such as maternal hypovitaminosis [12], air pollution [13], although specific diagnostic biomarkers have not yet been still established [14], but only hypothesized as hypothalamic neuropeptides variations [15]. The putative epigenetic mechanisms may act on global DNA methylation reprogramming during the embryonic development and the postnatal period for synaptogenesis peak time [16]. Moreover, ASD tend to impact the typical path development and impacting many behavioral areas such as hyperactivity, attentive lability and hyperkinetic behavior, linked to the autonomic dysregulation, altered sensory integration and to the disturbed sleep architecture [17-19]. Conversely, in typical developing children (TDC), EF emerges progressively during early childhood, with simpler EF skills emerging prior to more complex ones [11].

On this background, the current study aimed to investigate executive functions in an early age evaluating a group of ASD preschool children. The hypothesis was that ASD preschool children should show a lower level of executive functions, such as inhibition, shifting, emotional regulation, working memory, planning, than a control group of typical developing children.

Subjects and Methods

Participants

25 ASD preschool children (13 males, 12 females) aged between 2.7 years and 3.5 years, (mean age 3.09 ± 0.83) in rehabilitation clinics for developmental age were recruited from 2016 to 2017 in Campania Region in Italy. A control group of 25 typical developing children aged between 2.8 years and 3.5 years, (11 males, 14 females) (mean age 3.3 ± 0.61), coming from the same urban area, were also included. Exclusion criteria were: cognitive disability (IQ<70), neurological disorders (i.e., epilepsy), chromosomal syndromes (i.e., Down, Prader-Willi, trisomy 18, Fragile-X Syndrome). All participants were Caucasians and similar for socioeconomic status.

All parents gave written consent to participate to the study. The investigation was carried out in accordance with the principles of the Declaration of Helsinki [20]. The Internal Departmental Ethics Committee at the rehabilitation clinics approved the study (Internal Protocol number 2016/189).

Methods

Behavior Rating Inventory of Executive Function-Preschool Version (BRIEF-P): A widely used screening tool to evaluate executive functions in children was administered by trained clinical psychologist to parents of ASD and TDC groups, the Behavior Rating Inventory of Executive Function-Preschool Version (BRIEF-P) [21] according to the procedures described in a previous study by Smirni and colleagues [22].

The BRIEF-P allows an assessment of executive functions at a very early age (2- to 5-year-old children) and in living habitat, both in the clinical diagnosis and in the evaluation of the outcomes in a wide range of atypical development conditions. It is an ecological measure for the assessment of executive functions as perceived by their parents [21]. It consists of 63 items referring to behaviors in the last 6 months with 3 response options (0=never to 2=very often/always) showing the degree to which the behaviors are a problem. The higher the score the more relevant the problems. The questionnaire measures 5 domains mainly involved in executive dysfunctions in preschool age: inhibition (I), shift (S), emotions regulation (ER), working memory (WM) and planning/organization (PO). A Global Executive Composite score (GEC) represents an accurate consideration of the child's level of executive dysfunction.

Statistical Analysis

For comparison between the two groups (ASD and controls) the Student's -test and Chi-square test, where appropriate, were applied. Moreover, because of the relatively limited number of subjects recruited and in order to rule out possible type II errors, the effect size using Cohen's value was calculated. Cohen's is defined as the difference between two means divided by their pooled standard deviation. According to Cohen, 0.2 is indicative of a small effect, 0.5 of a medium effect size and 0.8 of a large effect size. P values<0.05 were considered statistically significant. For statistical analysis the software STATISTICA data analysis software system, version 6, StatSoft, Inc. 2001 was used. The effect size was calculated with the online software Social Science Statistics (https://www.socscistatistics.com/effectsize/default3.aspx).

Results

Participants' demographic characteristics are shown in Table 1. The two groups had no significant differences for age (p=0.777) and sex distribution (p=0.313).

Table 1. *Demographic characteristics.*

Group	N	M/F	Age		Age range
			Mean	SD	
ASD	25	13/12	3.09	0.83	2.7 - 3.5
TDC	25	11/14	3.3	0.61	2.8 - 3.5
All participants	50	24/26	3.19	0.72	2.7 - 3.5

N: Number; M: Males; F: Females; SD: Standard Deviation.

Table 2 shows the comparison between the two groups (ASD and TDC) among the BRIEF-P subscales expressed as mean and standard deviation (SD), according to t-Test analysis and the effect size expressed as Cohen's d. ASD children shows higher Inhibition (I) ($p< 0.001$) and Shift (S) subscales values ($p< 0.001$) with large effect size (1.463 and 1.195 respectively).

Table 2. *Comparison between the ASD and TDC groups for the BRIEF-p scales.*

Variables	ASD (N=25)		TDC (N=25)		t	p-value	Cohen's d
	Mean	SD	Mean	SD			
Inhibition (I)	63.44	10.72	48.32	9.94	5.171	0.000*	1.463
Shift (S)	63.64	8.65	52.6	9.78	4.227	0.000*	1.195
Emotional Regulation (ER)	61.44	11.66	54.96	13.3	1.832	0.073	0.518
Working Memory (WM)	56.72	11.41	56.52	10.38	0.065	0.949	0.018
Plan/Organize (PO)	52.24	8.08	50.32	7.75	0.857	0.396	0.242
Global Executive Composite (GEC)	55.48	9.17	53.92	9.66	0.586	0.561	0.166

Comparison between ASD preschool children and typical developing children (TDC) among BRIEF-P subscales: Inhibition (I), Shift (S), Emotions Regulation (ER), Working memory (WM) and Planning/Organization (PO).
For comparison between the two groups (ASD and controls) t-Test was applied and p values <0.05 were considered statistically significant (*).

Discussion

The current study investigated executive functioning in a group of ASD preschool children, compared to control group of typical developing children. BRIEF-P was administered to parents as a screening tool to identify the executive behavioral difficulties of their ASD children. ASD is a developmental disorder characterized by a triad of impaired domains: impaired social interaction and communication as well as repetitive behaviors and restricted interests [9].

In this study, parents of ASD children, compared to TDC parents, pointed out significant higher difficulties in two domains: inhibition and shift. According to their evaluations, the ASD children were less able to control and inhibit a prevalent response or a more meaningful behavior and to modify their behavior patterns in relation to emerging situations or to changed conditions or context, moving freely among different new activities, or different aspects of the same situation. Lower the differences between the two parents evaluations in the Emotional Control covering difficulties for modulating emotional response, where, however, ASD children showed greater difficulties than normal peers.

There were no significant differences in the assessments of the two groups of parents concerning the Working Memory and Plan/Organize domains. According to the parents, the two groups of children showed similar problems in holding information to complete a task (working memory) and similar difficulties to anticipate future events and take appropriate measures, or to put the information to reach a goal (Plan/Organize).

These findings seem to be an evidence of a prefrontal dysfunctionality already detectable in ASD children at an early age. Executive functions enable the normal person to shift attention flexibly, inhibit overpowering responses, generate goal-directed behavior, and solve problems in a planned and strategic way. Inhibition and shifting set are both executive functions depending upon the frontal lobes, and particularly on prefrontal cortex.

According to the executive dysfunction theory, executive dysfunction underlies many of the key features of autism as rigidity and perseveration, difficult to inhibit overpowering response, difficulties in the initiation of new non-routine actions and in analogy with frontal lobe patients who have impaired executive functions [4]. Shallice and Burgess [23] elaborated a cognitive model of executive function, centered on the frontal lobes and particularly on prefrontal cortex, where the Supervisory System, a higher-order system controlling non-routine operation, and a contention scheduler is involved in carrying out routine operations.

It is interesting to point out that a link between behavioral regulation executive processes (i.e., inhibition, shifting, and emotional control) and social skills has been reported as predictive in the TDC and ASD children [24]. Such relationship may be probably supported by a different pattern of electroencephalography (EEG) coherence respect of TDC children, as demonstrated by the significantly elevated theta coherence in the fronto-parietal network. Severity of executive dysfunction between high- and low-functioning children with ASD was found to be associated with the disordered neural connectivity in these children [25].

A very small minority of ASD children (about 6%) tend to show extraordinary skills such as high musical sensibility, exceptional computational skills, especially memory for numbers or dates, or unexpected talents as faithfully taking portraits or landscapes without possessing design concepts,

recite texts after simply reading or play music previously heard.

In clinical practice ASD children seem to show conflicting results about their cognitive and executive impairments that are scarcely probed in scientific literature, although generally lower than controls. Considering that the most recent data tend to emphasize the importance of early diagnosis and intervention, resulting in significant improvements in the areas cognitive, emotional and social, an early and intensive intervention allow a better development of skills cognitive, language and symptom reduction disorder and problematic behaviors. This concept may guide the whole clinical management for supporting all neurodevelopmental disorders in pediatric age [26-31].

We have to take into account as limitation of the present study the small sample size that we can justify because this one may be considered as a pilot study. The strong novelty of our report may be considered the EF evaluation on preschool-aged ASD children with an objective measurement as BRIEF-P but we have also to consider that the results are based on parental report. In general, identifying the EF disorders may lead to the correct rehabilitative program in order to support specific deficits in ASD children [32].

Conclusion

Despite the small sample examined, the results of this study confirmed the presence of a significant deficit in some aspects of executive functions in subjects with ASD. Furthermore, for the first time, the current study emphasized the emergence of such problems at a very early stage of the development, although further studies are needed.

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