Executive Functions and Developmental Profiles in Preschool Children with Autism Spectrum Disorder

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Abstract

Executive functions (EF) play a crucial role in overall human functioning. Children with Autism Spectrum Disorder (ASD) often have EF deficits. The goal of this study was to examine EF and developmental domains in preschool children with ASD. The sample for this study comprised 32 children (27 boys, mean age 65.3 months, SD- 4.0 months) with ASD. The control group consisted of 32 typically developing children (16 boys, mean age 64.3 months, SD- 5.1 months). EF were assessed with *Behavior Rating Inventory of Executive Function* and developmental domains were assessed with the *Developmental Assessment of Young Children*. The results of this study indicated that children with ASD do not have uneven EF and developmental profiles, although the EF and developmental domains scores were more heterogeneous than in typically developing children. Children with ASD had substantially lower EF and developmental scores than typically developing children. Implications of these results are discussed.

Introduction

Executive functions (EF) refer to a set of higher-order cognitive processes involved in goal-directed behavior (Tungate & Conners, 2021). They are very important for everyday functioning and as such are described as “cognitive toolkit of success” (Hendry et al., 2016). EF develop rapidly in early childhood and evidence clearly shows its importance for school readiness and academic success (Blair, 2016). Development of EF during childhood is of crucial importance for many later life outcomes, such as health and wealth (Thompson & Steinbeis, 2020). Recent research suggest that EF are multifaceted and that different types of EF are correlated but separable (Friedman et al., 2008). Most researchers agree that EF consist of a wide range of skills, including inhibition, mental flexibility, self-control, shifting of attention, initiation, impulsivity, working memory and planning (Garon et al., 2008; Gioia et al., 2002; McLean et al., 2014).

EF have been widely studied in typical and clinical populations. EF deficits are implicated in many neurological and psychiatric conditions including traumatic brain injury (Slomine et al., 2002), schizophrenia (Kluwe-Schiavon et al., 2013), and depression (Han et al., 2016). In addition to this, EF deficits are related to developmental disorders, including Attention Deficit Hyperactivity Disorder, Autism Spectrum Disorder, and Intellectual Disability (Barkley & Murphy, 2011; Happé et al., 2006; Memisevic & Sinanovic, 2014).

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social-communication domain and a pattern of repetitive sensory-motor behaviors (American Psychiatric Association, 2013; Lord et al., 2018). As the name implies, ASD is a very heterogeneous disorder with symptoms ranging from mild to severe (Kantzer et al., 2013). According to the 5th Edition of Diagnostic and Statistical Manual of Mental Disorders, ASD is categorized into three severity levels: Level 1 “Requiring support”, Level 2 “Requiring substantial support” and Level 3 “Requiring very substantial support” (American Psychiatric Association, 2013). ASD is a common neurodevelopmental disorder with current prevalence rate of 2.79% in children aged 3 to 17 years (Xu et al., 2019). Given the high prevalence rate, it is particularly important to identify ASD at an early age which, in turn, will lead to provisions of timely interventions and possibly improve the developmental trajectory of the disorder. Early intervention has been the topic of much scientific research in ASD and universal finding across studies is that the earlier intervention starts, the better are the outcomes (Ben Itzhak & Zachor, 2011; Landa, 2007; Smith, 1999). However, regardless of advances in early intervention, diagnosis of ASD is frequently delayed until preschool age (Steiner et al., 2012). Besides benefitting early intervention, early diagnosis is important for creation of an autism-friendly environment for the affected individuals, which means creating a setting in which everyone interacting with persons with ASD will have sufficient knowledge on appropriate modes of interaction and communication with them

(Fernel et al., 2013). Early identification and diagnosis of ASD will also lead to an in-depth assessment of children with ASD and identification of their strengths and weaknesses across developmental domains. The commonly assessed developmental domains at the preschool age are communication, cognition, social-emotional, motor, and adaptive behavior domain. Many studies have pointed to the uneven developmental profiles in children with ASD (Bernabei et al., 2003; Joseph et al., 2002; Li et al., 2020). Developmental differences in comparison with typically developing children are evident in the domain of motor skills, attention to social situations, visual reception, language skills (Girault & Piven, 2020). Knowing what developmental areas need additional professional attention and support may help in creating more efficient individualized support programs for children with ASD.

Much scientific attention has been directed to EF development in persons with ASD. It is widely recognized that children with ASD have deficits in EF which, consequentially, affect their adjustment and social skills. EF play a significant role in adaptive behavior of children with ASD, thus affecting their overall outcomes (Pugliese et al., 2015). Given the role EF play in everyday functioning, a rationale for the increasing research in this area stems from the notion that improvement in EF may lead to improvements in everyday functioning. Many studies have found relationship between social communication deficits and EF in children with ASD (McEvoy et al., 1993; Pellicano, 2012). However, the exact nature of this relationship is not clear. More specifically it is not clear whether EF deficits contribute to social and communication deficits or vice versa. Although there is a strong evidence of EF deficits present in persons with ASD, findings for the preschool age have been inconsistent (Garon et al., 2018) and require further scientific investigation. Thus, given the wide implications of EF deficits in ASD, we wanted to examine the relationship between EF and developmental domains in preschool children with ASD. The research questions we set to answer in this study were:

1. What is the relationship between EF and developmental domains in children with ASD and is this relationship different in typically developing children?
2. Do children with ASD have more heterogeneous scores in EF and developmental domains in comparison with typically developing children?
3. What are the differences in EF and developmental domains of children with ASD and typically developing children?
4. How ASD severity level affects EF and developmental domains?

Methods

Participants

The sample for this study consisted of 32 children with ASD (27 boys, mean age 65.3 months, SD- 4.0 months). Children with ASD were recruited from the Center for Early Intervention in Sarajevo that provides services to families and children with ASD. Children were referred to the Center after formal diagnosis of ASD was made by a neuropsychiatrist at the local clinic. The inclusion criteria were 1. Children had a formal diagnosis of ASD and 2. Parents accepted to participate in the study. The control group consisted of 32 typically developing children (16 boys, mean age 64.3 months, SD- 5.1 months) who, according to their parent's statements, did not have developmental disability. Typically developing children were recruited from two local kindergartens. The inclusion criteria were: 1. Children did not have a diagnosis of developmental disability and 2. Parents accepted to participate in the study. There were no statistically significant differences in the mean age of children with ASD and typically developing children ($t(62)=0.93$; $p=.36$).

Procedure

Parents of children with ASD who attended the Center for Early Intervention were asked to participate in the study. Parents provided basic demographic information for their children and granted permission to early special educators to complete the Developmental Assessment of Young Children scale (DAYC), the Behavior Rating Inventory of Executive Functions- Preschool Edition (BRIEF-P), and the Gilliam Autism Rating Scale for the purposes of this research. Total of 32 written consent forms were obtained and professionals (early childhood special educators) who have a wide experience of working with children with ASD and have worked with these children for at least two months completed the scales. Parents of typically developing children attending two local kindergartens were asked to participate in the study. After the written parental consent forms were received, early childhood educators completed BRIEF-P and DAYC for 32 typically developing children. The approval for this study was granted by the Faculty of Educational Sciences, University of Sarajevo.

Instruments

The *Developmental Assessment of Young Children* (DAYC, (Voress, 1998)) was created for the assessment of children from birth through 5 years 11 months across five Developmental domains: Cognitive, Communication, Social-Emotional, Physical Development, and Adaptive Behavior. The purpose of the scale is to identify children who might have developmental delays in any of these domains and to monitor child's progress across these domains. According to the manual, the reliability coefficients range from .90 to .99. Cronbach's alpha coefficients of internal reliability are above .90 for all scales. Administration time is 10-20 minutes per subtest (total time for administration is between 50 – 100 minutes). Raw scores were used in the analysis and higher scores mean better achievement.

The *Behavior Rating Inventory of Executive Function – Preschool Version* (BRIEF-P; (Gioia et al., 2003)) is an ecologically valid measure of executive functions intended for children aged 2-5.11 years. BRIEF-P consists of five clinical scales: Inhibit, Shift, Emotional Control, Working Memory, and Plan/Organize. These five clinical scales yield three indexes: Inhibitory Self-Control Index, Flexibility index, and Emergent Metacognition Index. The overall composite index is the Global Executive Index. For the purposes of this study we only used clinical scales of BRIEF-P. According to the BRIEF manual Cronbach's alphas for the BRIEF-P clinical scales ranges from $r = .80$ to $.90$ for parent version and from $.90$ to $.97$ for the teacher version.

The BRIEF-P takes 10-15 minutes to complete. Raw scores were used in the analysis and lower score means better executive function. We used Bosnian translation of the BRIEF-P (Dzambo et al., 2018).

The *Gilliam Autism Rating Scale – Third Edition* (GARS-3, (Gilliam, 2014)) was developed to screen for ASD in persons aged between 3 and 22 years. The GARS-3 consists of six clinical subscales: Restrictive/Repetitive Behaviors, Social Interaction, Social Communication, Emotional Responses, Cognitive Style, and Maladaptive Speech. These six clinical subscales are converted to Autism Index Composite score, a measure that was used in this study and indicates the severity of autism. Interclass correlation coefficients of the subscales are within the acceptable range ($r = .71 - .85$). Internal consistency, Cronbach's alpha is high and is above $.90$.

Statistical analysis

For the first research question, we calculated Pearson's correlation coefficients between EF (as measured by the BRIEF-P) and developmental domains (as measured by DAYC) for children with ASD and typically developing children. This helped us determine whether the EF and developmental profiles of children with ASD are uneven. We next separately standardized the scores of BRIEF and DAYC for each group of children and presented their

distribution to examine whether children with ASD have more heterogeneous score distribution within the EF and developmental domains than typically developing children. For the third research question, we performed independent t-tests and presented Cohen's effect size of mean differences in EF and developmental domains between children with ASD and typically developing children. Lastly, we calculated the Pearson correlation coefficients between autism severity (as measured by the GARS) on EF and Developmental domains. The statistical analysis was performed with the computer program SPSS v.27 (IBM, 2020).

Results

The first research question was to examine the relationship between EF and developmental domains.

Correlations between EF and developmental domains are shown in Table 1.

As can be seen from Table 1 there are strong, statistically significant, correlations of all variables (except for the pair *cognitive* and *physical* domain) within the developmental domains for children with ASD. In typically developing children, statistically significant correlations were observed for the correlations between cognition and communication domains, cognition and socio-emotional domains, and cognition and adaptive behavior domains. Other correlations were not statistically significant. These results indicate a stronger relationship within the developmental domains in children with ASD than in typically developing children. As for the correlations within the domain of EF for children with ASD, only two of the correlations were not statistically significant, the one between *working memory* and *shifting*, and the one between *working memory* and *emotional control*. In typically developing children, three correlations within the domain of EF were not statistically significant, the correlation between *emotional control* and *working memory*, the correlation between *emotional control* and *planning* and lastly the correlation between *inhibition* and *planning*. Again, the results show slightly stronger correlations within the domains of EF for children with ASD than for typically developing children. As for the correlations between EF and developmental domains, in children with ASD, there were four statistically significant correlations: 1. Working memory and adaptive behavior; 2. Working memory and communication; 3. Inhibition and adaptive behavior; and 4. Planning and adaptive behavior. In typically developing children, there were three statistically significant correlations: 1. Inhibition and Socio-emotional domain; 2. Planning and cognitive domain; and 3. Planning and Physical domain. These results indicate that overall EF domains and Developmental profiles are more strongly correlated in children with ASD than in typically developing children, which in turn indicates that children with ASD have more balanced profiles than typically developing children.

The second research question was to inspect standardized values of EF and developmental domains in children with ASD and typically developing children and to examine the spread of results. We first converted EF scores and developmental domains scores into standardized z-scores values separately for children with ASD and separately for typically developing children. In Fig. 1 and Fig. 2 we presented the interquartile range of these scores.

As can be seen from Fig. 1, EF profiles seem to be more heterogeneous in children with ASD, especially in the domains of emotional control and planning.

As can be seen from Fig. 2, developmental domains' profiles of children with ASD and typically developing children seem to be equally heterogeneous, except for the physical domain which seems to be more heterogeneous in children with ASD.

We next examined the mean scores differences in EF domains and Developmental domains between children with ASD and typically developing children. These results are shown in Table 2

There were statistically significant and large differences in favor of typically developing children on all EF and developmental domains mean scores. All effect sizes were large according to Cohen's criteria (Cohen, 2013). The largest differences in EF were for the variables working memory and inhibition, while the largest differences in developmental domains were in the area of communication and socio-emotional development. The last research question regards the correlation of the autism severity level as measured by the Gilliam Autism Rating Scale and EF domains and Developmental domains. These results are shown in Table 3.

The severity of autism symptoms as measured by GARS-3 is significantly related to EF domains of Shifting and Planning, and to the developmental domain of Cognition. The correlation between autism severity and working memory only narrowly fell short of reaching statistical significance ($p = .06$). All other correlations were not statistically significant.

Discussion

The goal of the present study was to investigate EF and developmental domains in preschool children with ASD and to compare their developmental profiles to profiles of typically developing children. The first finding of this study was that preschool children with ASD had more balanced EF and developmental domain profiles than typically developing children. We mentioned earlier some reports that children with ASD have unbalanced EF and developmental profiles, as indicated by strengths and weaknesses in various domains. Although this is certainly true for each individual child, it seems that on group level, EF and developmental profiles were more uneven in typically developing preschool children than in preschool children with ASD. These findings were in contrast with our expectations, as we expected to find lower correlations between various EF domains and developmental domains in children with ASD given the genetic and phenotypical heterogeneity of ASD (Skogli et al., 2020). However, it might be the case that EF and developmental profiles in children with ASD become more uneven at a later chronological age.

Our next research question was to determine the variability of results within the EF and developmental domains. The results of this study showed children with ASD had more variable EF scores than typically developing children on almost all EF clinical subscales. Although, on the group level, children with ASD had significant EF deficits, given the high variability in their scores, it is evident that some individuals with autism had smaller or even non-existing EF differences in comparison with typically developing children. This again points to the importance of examining differences on the individual level as well as on the group level. Understanding the individual differences of children with ASD might help practitioners in designing better treatment protocols (Geurts et al., 2014). Variability in the developmental domains was similar in both groups of children. The only remarkable difference was in the physical domain in which children with ASD had much more variability in the scores. As the physical domain is composed of both, fine motor skills and gross motor skills, the finding of greater variability in scores is not surprising. Earlier research has shown some children with ASD to have wide discrepancies in their fine and gross motor skills (Liu, 2013). On the other hand, there are also reports on similar level of development in fine and gross motor skills in children with ASD (Provost et al., 2007). In this study, fine and gross motor skills were not separately evaluated, but given the high variability in the scores it is clear there were children with balanced motor skills profiles (similar results in fine and gross motor skills) and children with unbalanced profiles (dissimilar results in fine and gross motor skills).

We found large, statistically significant, differences between children with ASD and typically developing children on all EF and developmental domains. In the area of EF, the largest differences were for the domain of working memory, followed by the inhibition, planning, emotional control and shifting. However, existing research does not point to the universal profile of weaknesses in EF that we found in our study. For example, other studies have also found significant EF differences in preschools with ASD and typically developing preschoolers in the domain of shifting

and inhibition but not on visual-spatial working memory tasks (Valeri et al., 2020). In a study that used the BRIEF-P for the assessment of EF, significant differences between preschoolers with ASD and typically developing children were again found on the subscales: inhibition and shifting but not on the subscale working memory (Carotenuto et al., 2019). On the other hand, there are studies that point to working memory as the main EF impairment in children with ASD (Baltruschat et al., 2011). In a large meta-analysis of 28 studies, involving 819 individuals with ASD has found significant impairments in working memory in this group in comparison to typically developing individuals (Wang et al., 2017). The possible reason on why individuals with ASD have impairments in working memory might be in the fact that they are deficient in the use of verbal mediation strategies that helps to maintain goal-related information in the working memory (Joseph et al., 2005). As for the differences in the studies regarding the role of working memory deficit in ASD, the potential explanation for these differences might be related to factors such as autism phenotype, intelligence and autism severity level which differ in participants across studies. It might be the case that in some children with ASD working memory is intact, while in the other children with ASD, working memory deficit is much more impaired.

Regarding the developmental profile, the largest differences between children with ASD and typically developing children were in the domain of communication and socio-emotional development, followed by adaptive behavior, physical domain, and cognitive domain. We expected to find these results given that defining features of ASD are deficits in communication and social skills. The findings in this study also indicate large differences in adaptive behavior between children with ASD and typically developing children. Earlier studies have also found large differences in adaptive behavior of individuals with ASD and typically developing individuals (Kanne et al., 2011; Volkmar et al., 1987). Adaptive behavior was significantly related to three executive functions in preschool children with ASD: inhibition, working memory, and planning. These results can be informative in the context of identifying the EF subdomains as a potential target for improving adaptive behavior skills (Tomaszewski et al., 2020) and communication skills (Weismer et al., 2018).

Autism severity was statistically significantly correlated with two executive functions: shifting and planning. The results in our study are in line with earlier studies that found people with autism to have particular deficits in shifting and planning (Blijd-Hoogewys et al., 2014). We have now found these significant relationships to be present in preschool children with ASD as well. Interestingly, the autism severity level was statistically significantly correlated only to the developmental domain of cognition, although we expected it to be significantly correlated with other domains as well, especially with the domain of communication. However, this lack of effect was probably because the cognition domain shared much of the common variance with other developmental domains.

Identification of EF deficits in children at an early age will help create programs aimed at ameliorating these deficits. Earlier research has shown that it is possible to improve EF in preschool children (Volckaert & Noël, 2015). This is especially relevant for children with ASD. Some reports showed that Early Intensive Behavioral Training can significantly improve EF in children with ASD (Skogli et al., 2020). Behavioral intervention, through the use of positive reinforcement, has the potential to significantly improve working memory in children with ASD (Baltruschat et al., 2011). Programs that aim flexibility, goal-setting, and planning significantly improve EF in children with ASD and also improve social skills (Kenworthy et al., 2014). Besides these programs, it is also noteworthy to mention physical activities as an efficient way to improve EF in children with ASD. Many studies have shown positive effects of martial arts (Phung & Goldberg, 2019) and exergaming (Hilton et al., 2014) on EF. In addition, physical activity has also been found to have a positive effect on academic achievements of children with ASD (Nakutin & Gutierrez, 2019). Educators have many evidence-based interventions at their disposal to improve EF in children with ASD. Better

understanding of EF deficits in ASD and individual EF and developmental profiles will lead to better intervention programs at an early age.

There are several limitations of this study that need to be noted. First of all, we used only one measure of EF domains (BRIEF-P) and developmental domains (DAYC) in this study. It would be useful if we have used parental's report as well, which would increase the reliability of the results. Second, it would also be useful if we have used some performance-based measures of EF. Third, the sample size was relatively small, thus reducing the generalizability of the results. On the other hand, the mean differences in EF and developmental scores were exceptionally large, so there was a minimal risk of committing a type I error.

Conclusions

Children with Autism Spectrum Disorder had more balanced EF and developmental profiles than typically developing children. There is much more interindividual variability in EF and developmental domain scores in children with ASD than in typically developing children. Preschool children with ASD had significantly lower EF and developmental domains scores than typically developing children. Autism severity level had a significant effect on shifting and planning domains of executive functions, as well as on the cognitive domain within the developmental profile.

Declarations

Conflict of interest: On behalf of all authors, the corresponding author states that there is no conflict of interest

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Tables

Table 1

Correlations between EF and Developmental domains

	<i>Variables</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>
<i>Developmental domains</i>	<i>Cognitive</i>	_____	.44	.39	.34	.42	-.04	.21	.14	-.19	-.42
	<i>Communication</i>	.66	_____	.28	.24	.29	-.12	-.30	-.07	-.17	-.28
	<i>Social-Emotional</i>	.63	.66	_____	.26	.25	-.37	.02	-.32	-.07	-.12
	<i>Physical</i>	.31	.41	.40	_____	.05	-.05	-.23	.04	-.16	-.54
	<i>Adaptive behavior</i>	.75	.76	.59	.57	_____	.01	.01	-.13	.14	.02
<i>Executive functions</i>	<i>Inhibit</i>	-.25	-.35	-.08	-.26	-.38	_____	.38	.76	.46	.29
	<i>Shift</i>	-.32	-.23	-.21	-.30	-.35	.58	_____	.66	.48	.38
	<i>Emotional Control</i>	-.09	-.18	.05	-.16	-.06	.67	.70	_____	.34	.12
	<i>Working memory</i>	-.34	-.38	-.35	-.23	-.54	.36	.13	.10	_____	.78
	<i>Planning</i>	-.30	-.33	-.11	-.32	-.44	.78	.48	.40	.59	_____

Note. Correlations below diagonal line are for children with ASD, and above the line are for typically developing children. Correlations in bold font are statistically significant at $p < .05$ level.

Table 2

Group differences for EF domains and Developmental domains between children with ASD and typically developing children

	Variable	Children with ASD		Typical children		t (62)*	Cohen' d
		M	SD	M	SD		
EF domains	Inhibit	41.7	6.2	19.9	5.2	15.3	3.8
	Shift	23.4	5.4	11.2	2.4	11.7	2.9
	Emotional Control	25.0	4.8	11.8	4.0	11.9	3.0
	Working memory	46.5	5.7	21.4	5.9	17.3	4.3
	Planning	26.2	4.5	12.4	3.3	14.0	3.5
Developmental domains	Cognitive	25.6	15.0	66.7	8.1	-13.7	-3.4
	Communication	20.7	16.3	71.9	5.2	-17.0	-4.2
	Socio-emotional	15.3	13.4	55.8	2.0	-16.9	-4.2
	Physical	54.5	10.5	82.8	4.2	-14.1	-3.5
	Adaptive	26.7	10.6	58.0	2.2	-16.5	-4.1

Note. * all p's are $< .001$.

Table 3

The Pearson correlation of the Gilliam Autism Rating Scale and EF domains and Developmental domains

		Gilliam Autism Rating Scale	
Variable		r	p
EF domains	Inhibit	.31	.10
	Shift	.35	.04
	Emotional Control	.29	.10
	Working memory	.33	.06
	Planning	.42	.01
Developmental domains	Cognitive	-.41	.02
	Communication	-.26	.15
	Socio-emotional	-.11	.55
	Physical	-.30	.10
	Adaptive	-.31	.10

Note. N=32. Values in bold are statistically significant at $p < .05$ level.

Figures

Figure 1

Interquartile range of standardized values of EF domains in children with ASD and typically developing children

Figure 2

Interquartile range of standardized values of Developmental domains in children with ASD and typically developing children