Neuropsychology
2013, Vol. 27, No. 1, 13–18


0894-4105/13/$12.00 DOI: 10.1037/a0031299

# Impairments in Real-World Executive Function Increase From Childhood to Adolescence in Autism Spectrum Disorders

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***Objective:*** Although several studies have investigated developmental trajectories of executive functioning (EF) in individuals with autism spectrum disorders (ASD) using lab-based tasks, no study to date has directly measured how EF skills in everyday settings vary at different ages. The current study seeks to extend prior work by evaluating age-related differences in parent-reported EF problems during childhood and adolescence in a large cross-sectional cohort of children with ASD. ***Method:*** Children ($N = 185$) with an ASD without intellectual disability participated in the study. Participants were divided into four groups based on age (5–7, 8–10, 11–13, and 14–18-year-olds). The four age groups did not differ in IQ, sex ratio, or autism symptoms. ***Results:*** There were significant age effects (i.e., worsening scores with increasing age) in three of G. A. Gioia, P. K. Isquith, S. Guy, and L. Kenworthy's (2000) *BRIEF: Behavior Rating Inventory of Executive Function*, Odessa, FL, Psychological Assessment Resources scale scores: Initiate ($p = .007$), working memory ($p = .003$), and organization of materials ($p = .023$). In addition, analysis of the BRIEF scale profile revealed that, although multiple scales were elevated, the shift scale showed the greatest problems in both the youngest and oldest age cohorts. ***Conclusions:*** Older children with ASD show greater EF problems compared with the normative sample than younger children with ASD. Specifically, there is a widening divergence from the normative sample in metacognitive executive abilities in children with ASD as they age. This, in combination with significant, albeit more stable, impairments in flexibility, has implications for the challenges faced by high-functioning individuals with ASD as they attempt to enter mainstream work and social environments.

*Keywords:* autism, executive function, BRIEF, development, age-related



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We thank the families of the participants and the diagnostic team that characterized the participants for their efforts over the years. This research was supported by the Intramural Research Program of the United States Department of Health and Human Services, National Institutes of Health, National Institute of Mental Health (NIMH). B. E. Yerys was supported by the NIMH Grant 5K23MH86111. L. Kenworthy was supported by the Isadore and Bertha Gudelsky Foundation.

Conflicts of Interest: Lauren Kenworthy receives financial compensation for use of the BRIEF. The other authors have no conflicts of interest.

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Executive dysfunction is frequently associated with autism spectrum disorders (ASDs; for review, see: Hill, 2004; Kenworthy, Yerys, Anthony, & Wallace, 2008) and has been linked to reduced adaptive functioning (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002) and greater autism symptoms in individuals with ASDs (Yerys et al., 2009; Kenworthy, Black, Harrison, Della Rosa, & Wallace, 2009). Executive dysfunction in children with ASDs is not universal, and there is evidence that executive function (EF) impairments occur in older children with ASD but not younger ones (e.g., Hill, 2004; Yerys, Hepburn, Pennington, & Rogers, 2007). This literature is difficult to interpret however, because EF is a complex construct, with multiple processes that mature at different times in typical children and have not been consistently measured across ASD studies (Kenworthy et al., 2008).

The maturation of EF during typical development follows a protracted course, which varies by the process under scrutiny and level of complexity of the task. For example, a recent review by Best and Miller (2010) argues that the ability to control or prevent an automatic behavioral response (i.e., inhibition) develops earlier than other executive processes in typically developing children. Specifically, inhibition improves rapidly during early childhood (e.g., Gerstadt, Hong, & Diamond, 1994), followed by slower improvements through adolescence (Best & Miller, 2010). In contrast, maintaining information in mind in the face of interference (i.e., working memory) appears to improve in a more linear, gradual fashion from preschool through childhood and adolescence (e.g., Conklin, Luciana, Hooper, & Yarger, 2007). The ability to shift between task sets (i.e., flexibility) also follows a more protracted developmental course, with successful switching on complex tasks occurring by middle adolescence (e.g., Huizinga, Dolan, & van der Molen, 2006). In reviewing this literature, Best and Miller note the importance of measuring multiple EF processes across development in order to capture the emergence of these interdependent, but distinguishable abilities. They also emphasize that future studies should distinguish EF development beyond the preschool years, and that the complexity of tasks tapping specific executive processes is a key factor in determining the age at which a task is mastered. Furthermore, self-monitoring, inferencing, error detection, and integration of multiple functions all make a particular EF task "higher level" and extend age of mastery into early adulthood (O'Hearn, Asato, Ordaz, & Luna, 2008).

Most of the studies cited above rely on highly controlled lab-based tasks to determine EF development. Huizinga and Smidts (2011) augmented this data by examining age-related EF differences in a large normative sample using the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), an informant-report questionnaire developed to identify everyday EF abilities in children between the ages of 5–18 years. The BRIEF measures two broad areas of EF: *behavioral regulation*, the ability to shift and modulate emotions and behavior via appropriate inhibitory control; and *metacognition*, the ability to cognitively self-manage tasks and monitor performance. Parent-reported EF problems generally decreased with increasing age in typically developing children, with much of these differences driven by behavioral regulation rather than metacognitive processes. Specifically, 5–8-year-olds showed significantly more problems than 9–11-year-olds in emotional control, inhibition, shifting, and working memory, and 12–14-year-olds were more impaired than their 15–18-year-old counterparts on scales of inhibition and emotional control. These findings may appear to contradict those of Best and Miller (2010; i.e., improvement in metacognitive skills, such as working memory, with increasing age), however, unlike lab tasks, the BRIEF measures parent report of *problem* behavior in the context of *everyday* demands. In other words, limited raw score change on the BRIEF over time reflects an individual's ability to keep pace with real-world behavioral expectations. Everyday metacognitive demands for organization, planning, and working memory increase dramatically as children become adolescents and enter secondary school settings with multiple teachers, longer term assignments, and more cumulative testing. Thus, these findings can be understood as complementing those of lab-based studies, and reflecting how typically developing children successfully adapt to increased EF demands in their environment.

Understanding the trajectory of EF development in ASD can offer insight into the dynamic nature of the disorder and inform treatment options. In addition, it can inform research findings of abnormal neuroanatomical growth across childhood (e.g., Courchesne, Campbell, & Solso, 2011; Wallace, Dankner, Kenworthy, Giedd, & Martin, 2010) and its relation to EF in ASD. Moreover, exploration of developmental trajectories of EF in ASD could be helpful in reconciling apparently contradictory findings of impaired and preserved EF stemming from studies of children of different ages.

In a comprehensive review of EF development in school-age children with ASD, O'Hearn and colleagues (2008) suggested overall age-related improvement on lab-based measures, yet an inability to attain normal performance levels. Similarly, Luna, Doll Hegedus, Minshew, and Sweeney (2007) found that in school-age children with ASD, inhibition and working memory skills improved over time yet were slower to mature and lagged behind skills in same-age typical peers. Several studies of school-age children, both cross-sectional (Happé, Booth, Charlton, & Hughes, 2006) and longitudinal (Pellicano, 2010) have also suggested age-related gains in EF skills, whereas others have reported no improvement (Ozonoff & McEvoy, 1994). In general, the literature supports the notion that EF skills improve through childhood and adolescence in ASDs, but they mature at a slower pace and often remain impaired into adulthood.

The aforementioned studies rely on lab-based measures of EF. It is useful to supplement these findings with data collected on everyday EF measures, such as the BRIEF. The BRIEF offers the further advantage of sampling multiple EF processes (inhibition, shifting, emotional control, initiation, working memory, planning and organization, organization of materials, and self-monitoring) across a wide age range (5–18 years). The purpose of the current investigation is to extend prior studies by evaluating age-related differences in everyday EF during childhood and adolescence in a large ASD cohort. Although some prior research using lab-based tasks reports modest EF improvements in ASD during school age, the greatly increased real-world expectations for EF skills in older adolescents versus young children may create a greater divergence in the severity of parent-reported EF problems between children with ASD and their peers as they progress through adolescence. We therefore hypothesize that children with ASD will show greater EF impairments across age than normative samples, as we

predict will be indicated by increasing scores (which indicate greater problems) on the BRIEF scales with age.

## Method

### Participants

A total of 185 children with an ASD participated in the study. The study received institutional ethics approval from the Institutional Review Board of Children's National Medical Center, Rockville, Maryland, and written informed consent was obtained from all participants. Children were recruited through a hospital clinic in Maryland specializing in ASD and neuropsychological assessment. All individuals were diagnosed by trained, experienced, research-reliable clinicians, (i.e., $\kappa \geq .80$ on the Autism Diagnostic Observation Schedule; ADOS; Lord et al, 2000) with a high-functioning ASD using *DSM–IV-R* criteria (APA, 2000) and qualified for a "broad ASD" on the Autism Diagnostic Interview/Autism Diagnostic Interview-Revised (ADI/ADI-R; Le Couteur et al., 1989; Lord, Rutter, & Le Couteur, 1994) and/or the ADOS (Lord et al., 2000) following the criteria established by the National Institute of Child Health and Human Development/National Institute on Deafness and Other Communication Disorders Collaborative Programs for Excellence in Autism (Lainhart et al., 2006). The "broad ASD" criteria included meeting the ADI-R cutoff for autism in the social domain and at least one other domain, or meeting the ADOS ASD cutoff for the combined social and communication score. All but 18 participants had a full scale IQ (FSIQ) ≥70; IQ for the remaining 18 participants was estimated from a verbal IQ composite score. IQ was measured by the *Wechsler Intelligence Scale for Children*, 3rd ed. ($n = 2$; Wechsler, 1991) or 4th ed. ($n = 59$; Wechsler, 2004); *Wechsler Abbreviated Scale of Intelligence* ($n = 114$; Wechsler, 1999), differential abilities scale, 2nd ed. ($n = 5$); *Wechsler Adult Intelligence Scale*, 3rd ed. ($n = 3$; Wechsler, 1997); or the *Wechsler Preschool and Primary Scales of Intelligence*, 3rd ed. ($n = 2$; Wechsler, 2002). We excluded participants if they had any reported history of comorbid genetic or neurological disorders (e.g., Fragile X syndrome, Tourette's syndrome). Diagnostic and neurobehavioral data were sometimes collected at different time points; therefore, those children who had more than two years between data collection points were excluded from the study.

Participants were divided into four groups based on age (5–7, 8–10, 11–13, 14–18-year-olds), consistent with the age subdivisions described in the BRIEF normative sample (Gioia et al., 2000). The number of participants at each age was as follows: 5 years = 6, 6 years = 10, 7 years = 18, 8 years = 31, 9 years = 19, 10 years = 15, 11 years = 15, 12 years = 18, 13 years = 17, 14 years = 8, 15 years = 9, 16 years = 9, 17 years = 4, 18 years = 6. Analyses confirmed that these age groups did not differ in our sample in terms of socioeconomic status (SES), sex ratio, or IQ. Furthermore, to ensure that ASD symptoms were not different across the age groups and therefore would not impact any age-related effects in EF, we divided subjects into three categories based on their ADOS scores: (a) Mild ASD, defined as children who met clinical *DSM–IV-R* (APA, 2000) criteria for an ASD in addition to the ADI cut-off for autism, but the ADOS social plus communication score was below the ASD cut-off; (b) ASD, defined as children who met clinical *DSM–IV-R* and ADOS cut-offs for an ASD in addition to the ADI cut-off for autism; and (c) autism, defined as children who met *DSM–IV-R* criteria for an ASD, as well as ADI and ADOS cut-off scores for autism). Comparison of the ratio of diagnostic categories between the four different age bins revealed no significant differences. See Table 1 for complete demographic information.

### Measures

The ADI/ADI-R (Le Couteur et al., 1989; Lord et al., 1994) is a detailed parent/primary-caregiver interview of developmental history and autism symptoms. Scores are aggregated into symptom clusters that correspond to *DSM–IV-R* (APA, 2000) criteria for a diagnosis of autism. The ADOS (Lord et al., 2000) is a structured play and conversational interview that includes a series of social presses and other opportunities to elicit symptoms of an ASD.

The parent form of the BRIEF (Gioia, Isquith, Guy, & Kenworthy, 2000) assesses EF in everyday situations and is comprised of eight scales (initiate, emotional control, shift, inhibit, organize/plan, organization of materials, working memory, monitor), which are collapsed into two broad indices: the behavioral regulation index (BRI) and the metacognition index (MCI). Results are reported as *t* scores. Higher scores indicate greater impairment; *t* scores ≥ 65 (i.e., 1.5 + *SD*s above the mean) indicate clinically significant ratings. Dependent variables were the eight scales.

## Results

Inspection of BRIEF variables revealed a total of nine outliers (i.e., scores beyond 2.5 *SD*s of the mean of the constituent age



Table 1
*Participant Demographics by Age Group*

| Variable | Total sample ($n$ = 185) | 5–7 Years ($n$ = 34) | 8–10 Years ($n$ = 65) | 11–13 Years ($n$ = 50) | 14–18 Years ($n$ = 36) | $F/\chi^2$ | $p$ |
|---|---|---|---|---|---|---|---|
| Sex (%M %F) | 83%M 17%F | 85%M 15%F | 85%M 15%F | 76%M 24%F | 86%M 14%F | 2.19[a] | .534 |
| *SES* mean* | 1.89 | 1.91 | 1.93 | 1.94 | 1.74 | 8.9 | .712 |
| Full-scale IQ mean (*SD*) | 105.75 (18.91) | 100.35 (16.45) | 106.42 (20.55) | 109.38 (19.07) | 104.58 (17.16) | 1.63[b] | .185 |
| ADOS classification (Mild ASD/ASD/AD)** | 25/40/116 | 9/9/16 | 8/15/42 | 5/8/35 | 3/8/23 | 7.88[a] | .247 |

*Note.* ADOS = Autism Diagnostic Observation Schedule; ASD = autism spectrum disorder; AD = autistic disorder.
[a] Chi-square. [b] *F* value.
* Mother's occupational level used to estimate socioeconomic status (SES). Values are as follows: 1 = Graduate degree; 2 = College graduate; 3 = Partial college; 4 = High school plus technical school; 5 = High school. ** See the Methods section for explanation of ADOS classifications; six children are not categorized due to insufficient ADOS data.

group), which were adjusted by moving the outlier score to 2.5 *SD*s beyond the age-group mean and adding one *t* score point. None of the BRIEF data presented with significant kurtosis or skew after adjustment of *t* scores. A series of eight one-sample *t* tests confirmed that mean scale values for the ASD group as a whole were significantly elevated on all scales relative to the normative sample, ($ts > 9.14$, $ps < .001$). A mixed-model ANOVA with age group as the between-subjects factor and BRIEF scale as the within-subjects factor revealed a main effect for scale, $F(1, 181) = 34.33$, $p < .001$, $\eta_p^2 = .16$)and an interaction between scale and age group, $F(3, 181) = 1.82$, $p = .022$, $\eta_p^2 = .03$ (see Table 2), but no significant main effect of age group, $F(3, 181) = 2.20$, $p = .09$, $\eta_p^2 = .03$. Subsequent one-way ANOVAs revealed age effects for the following scales: Initiate, $F(3, 181) = 4.21$, $p = .007$, $\eta_p^2 = .06$; working memory, $F(3, 181) = 4.88$, $p = .003$, $\eta_p^2 = .07$; and organization of materials, $F(3, 181) = 3.25$, $p = .023$, $\eta_p^2 = .05$. Post hoc analyses revealed significantly higher (more impaired) initiate (Tukey's corrected $p = .003$) and working-memory (Tukey's corrected $p = .001$) scale scores in the 14–18 year olds than in the 5–7 year olds. Finally, repeated measures ANOVAs (with BRIEF scale as the within-subjects factor) were run in order to identify the BRIEF scales showing the greatest EF problems in the youngest and oldest groups (since those were the groups driving the age by BRIEF scale interaction). Significant within-group BRIEF scale score differences, $F(1, 33) = 4.97$, $p = .001$, $\eta_p^2 = .13$ and $F(1, 35) = 11.52$, $p < .001$, $\eta_p^2 = .25$, respectively, were found in both groups. In the youngest group, the shift scale was the highest *t* score and was significantly higher than three of the other scales. The monitor scale was also significantly higher than three other scales. In the oldest group, the shift scale was significantly higher than six other scales, whereas the next highest *t* score (working memory) was significantly higher than five other scales. Exploration of possible IQ-score influences on age-related differences in the BRIEF revealed that the findings from the ANOVAs presented above were not altered after adding IQ as a covariate.

## Discussion

This is the first study to evaluate age-related differences in everyday EF in a large group of children with ASD. Findings generally confirmed the hypothesis that children with ASD show increasing EF impairments with age compared with the children in the normative sample. Specifically, parents of older children with ASD reported more severe problems on several of the metacognitive scales of the BRIEF. These age-related findings in EF were not due to differences in IQ, sex ratio, or autism symptomatology, as the four age groups were matched on these variables. Additionally, all analyses survived IQ covariation, and were generally of medium effect size. Although some (e.g., Dennis et al., 2009) argue that covarying IQ can remove variance relevant to the experimental question, in this case it did not change the findings.

The current finding of increased parent-reported problems with metacognitive abilities in older children and adolescents with ASD is in contrast to a report of general improvement in everyday EF in typically developing children (Huizinga & Smidts, 2011). Specifically, parents of older children with ASD report greater problems than parents in the normative sample in the domains of task and self-initiation, working memory, and organization of materials. Our findings are consistent with the results of Luna and colleagues (2007) of slower-to-mature working memory and EF skills in ASD on laboratory measures; unlike their typically developing peers, metacognitive abilities in ASD may not be improving rapidly enough in late childhood and adolescence to keep pace with increased environmental demands. This pattern confirms what is often observed clinically: The gap between environmental expectations and the actual ability of a child with ASD to follow multistep directions, keep school materials organized, and be a "self-starter" widens over time.

Although the shift scale score does not significantly change across the four age groups we investigated, it is the peak area of weakness in both the youngest and oldest age groups. Moreover, not only is the shift scale the highest mean score in the total sample, but it is also the only mean score that is consistently above the clinical cut-off of $t = 65$ across all of the age groups. This converges with EF studies of ASD using lab-based measures of flexibility, such as the Wisconsin Card Sorting Test (Psychological Assessment Resources, 2003) and the Intradimensional/Extradimensional Shift Test (e.g., Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Lopez, Lincoln, Ozonoff, & Lai, 2005; Yerys et al., 2009).

Table 2
*Age-Group Differences In BRIEF Scale Scores*

| BRIEF Scales[a] | Total ($n = 185$) | 5–7 Years ($n = 34$) | 8–10 Years ($n = 65$) | 11–13 Years ($n = 50$) | 14–18 Years ($n = 36$) | *F* value | *p* | Post-hoc testing[b] |
|---|---|---|---|---|---|---|---|---|
| Behavioral regulation index | 66.48 (12.15) | 64.24 (10.84) | 66.20 (10.74) | 67.68 (14.16) | 67.42 (12.86) | — | — | — |
| Emotional | 61.42 (12.06) | 59.47 (11.34) | 61.63 (10.58) | 62.94 (14.35) | 60.75 (11.94) | .60 | .615 | *ns* |
| Inhibit | 63.63 (12.59) | 63.35 (11.10) | 62.77 (11.66) | 64.54 (12.43) | 64.19 (15.77) | .22 | .886 | *ns* |
| Shift | 69.38 (12.93) | 66.06 (13.59) | 69.37 (12.34) | 68.74 (13.61) | 73.44 (11.76) | 2.00 | .115 | *ns* |
| Metacognition index | 66.34 (11.15) | 62.59 (12.16) | 66.20 (10.74) | 65.88 (10.84) | 69.36 (9.31) | — | — | — |
| Initiate | 64.21 (11.50) | 59.65 (11.05) | 64.11 (11.51) | 63.90 (11.56) | 69.14 (10.25) | 4.21 | .007* | 14–18 > 5–7 |
| Working memory | 67.33 (11.61) | 62.47 (12.27) | 67.35 (10.17) | 66.74 (11.60) | 72.69 (11.69) | 4.88 | .003* | 14–18 > 5–7 |
| Planning and organization | 64.86 (12.05) | 62.62 (14.03) | 64.77 (12.86) | 64.44 (11.04) | 67.72 (9.50) | 1.09 | .353 | *ns* |
| Organization of materials | 57.49 (11.14) | 54.32 (11.96) | 59.69 (10.61) | 55.04 (11.18) | 59.92 (10.16) | 3.25 | .023* | *ns* |
| Monitor | 65.56 (11.29) | 63.74 (11.91) | 64.60 (11.08) | 66.8 (12.13) | 67.31 (9.77) | .94 | .423 | *ns* |
| Global executive composite | 67.74 (11.07) | 64.41 (10.52) | 67.85 (11.05) | 67.84 (12.04) | 70.56 (9.71) | — | — | — |

[a] All scores reported as *t* scores; $M = 50$; $SD = 10$; *t* scores $\geq 65$ are considered clinically significant. [b] Tukey's.
* Significant at $p < .05$.

To our knowledge, the present study is the largest to date to evaluate EF development in ASD, but it examines cross-sectional age effects, rather than using a more powerful longitudinal design. It also relies on standardized scores rather than raw data and it lacks a control group, which limits interpretation of findings to relative differences compared with typically developing children. Future areas for study include longitudinal analyses of raw EF data, which could address questions about whether EF abilities of children with ASD are progressing slowly, not progressing at all, or worsening. Another potential limitation of using *t* scores rather than raw data is the presence of artificial basal or ceiling effects. Analysis of the BRIEF psychometric properties confirmed no ceiling or basal effects influencing findings; however, relatively lower scores on the organization of materials scale may reflect the limited range of scores one can achieve in this scale (Gioia et al., 2000). We also excluded children with intellectual disability from the study, and therefore findings may not generalize to the entire ASD population. In addition, IQ estimates were drawn from different assessment tools which may not be entirely comparable. Despite being the largest study to date assessing EF development, replication using larger samples, especially in the youngest and oldest groups, would strengthen the findings. Finally, this study lacks lab-based measures and other informant report (i.e., teacher), which would complement the parent report of EF skills.

## Conclusion

This study examined age-related differences in everyday EF within a large sample of children and adolescents with ASD, utilizing a measure of parent ratings. Findings support previous literature that EF (particularly metacognitive abilities) in ASD matures at a slower rate than it does in typically developing children and thus shows greater divergence from normative samples with increasing age. Whereas flexibility remains particularly impaired across ages in ASDs, working memory, initiation, and organization, become increasingly problematic over time, according to parent report. The implications of these findings for people with ASD emphasize the need for continuing EF intervention and support throughout later adolescence, a time when school and clinical resources may not be as readily available.

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Received April 4, 2012
Revision received November 12, 2012
Accepted November 13, 2012 ■