Journal of Autism and Developmental Disorders
https://doi.org/10.1007/s10803-019-03958-6

ORIGINALPAPER

# Parent Reports of Executive Function Associated with Functional Communication and Conversational Skills Among School Age Children With and Without Autism Spectrum Disorder

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**Abstract**
Despite average or above cognitive and verbal abilities, many children with autism spectrum disorder (ASD) experience difficulties in functional and social communication. Executive functioning (EF) may be the cognitive and regulatory mechanism that underlies these difficulties. Parents rated 92 children with ASD as demonstrating significantly more challenges than 94 typically developing children on measures of EF (Behavior Rating Inventory of Executive Function; BRIEF), functional communication (FC), and verbal conversation (VC) skills. For both groups, the BRIEF metacognition scale emerged as a strong predictor of FC, while the BRIEF behavior regulation and the inhibit scale were predictive of VC skills. These findings suggest that targeting EF domains specifically may improve FC and VC skills in children with ASD.

**Keywords** Behavior rating inventory of executive function · Behavior assessment system for children-second edition · Multidimensional social competence scale · Verbal conversation · Youth

Although difficulties in communication are common to all children with Autism spectrum disorder (ASD) there is variability in how these manifest. Whereas the majority of children with ASD demonstrate fluent speech (Wodka et al. 2013) and at least 30% of children with ASD who were nonverbal until at least 5 years of age will eventually achieve phrase speech (Pickett et al. 2009), the ability to communicate effectively remains challenging in most cases. Even children with ASD who are quite proficient with verbal expression, tend to have low functional communication (FC) skills (e.g., not able to ask for help, Norbury 2014). FC is broadly defined as a child's ability to communicate in a way that others can comprehend and reciprocate (Reynolds 2004) with purpose or intent relevant to the context (e.g., interaction with one's parent, teacher; Hartley 1990). Specifically for children with ASD, a FC response may take many forms including words, gestures, picture exchange systems, or assistive technology devices (Brady and Halle 1997). FC is an important aspect of children's day-to-day interactions with a variety of people including parents, educators, and clinicians. Children with ASD who have better FC (e.g., the ability to express a need or a want to others) are less likely to exhibit challenging behaviors (Mancil 2006). Thus, FC may be an important target of intervention for children with ASD to improve their social communication.

Conversation is another form of communication that goes beyond functional or instrumental goals for the individual, but also involves social goals such as sharing and reciprocating. Here, the pragmatics of communication, the social rules and conventions (e.g., greeting, and turn taking), are the critical elements of effective interchange. Although many individuals with ASD are sufficiently proficient with language skills (e.g., adequate articulation, vocabulary, and grammar skills), they have difficulty with conversation skills including initiating conversations, introducing new topics, maintaining and extending topics through the use of follow-up questions, and turn taking (Jones and Schwartz 2009; Paul et al. 2009; Yager and Iarocci 2013). Further, difficulties with conversation skills often interfere with social opportunities and friendship making, especially during adolescence when conversation is the primary mode of social engagement (Carter

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Published online: 07 March 2019

et al. 2014). The pragmatics of conversation may also be a key target of intervention to improve social communication in children with ASD.

In both FC and the pragmatics of conversation, EF may be the underlying cognitive and regulatory mechanism implicated in the social communication deficits observed in children with ASD. This would explain why despite adequate general cognitive ability (as indexed with IQ) and language skills (e.g., expressive vocabulary) children with ASD struggle to communicate effectively for functional and pragmatic purposes. Broadly, EF refers to higher order cognitive processes (e.g., working memory, inhibition, organization, planning, and flexibility or set shifting) thought to regulate goal-directed thoughts and actions (Zelazo and Müller 2010). Executive dysfunction has been observed in some studies of children with ASD that have measured working memory (e.g., backward span task; Joseph et al. 2005), inhibition (e.g., Luria's Hand game; Pellicano 2007), and shifting (e.g., flexible item selection task; Kimhi et al. 2014), which could impact the ability to hold in mind critical aspects of conversation, inhibit the impulse to interrupt another person who is speaking, or shift from one meaning of a phrase/word to another meaning (Landa and Goldberg 2005). Many children with ASD have communication and EF challenges; however, the evidence is mixed with regard to if, and how, these difficulties are related (e.g., Mashal and Kasirer 2012).

EFs are traditionally assessed using standardized measurements administered in highly structured and controlled environments. These performance-based measures are useful as they provide insight into the individual cognitive components of EF (e.g., inhibition, flexibility, working memory); however, they are not usually predictive of EF in an everyday context (Gardiner et al. 2017; Toplak et al. 2013). Ratings of EF assess how well children are able to ignore distracting information, shift from one activity to another, among other skills. Thus, some have argued that behavior-rating scales consider EF from a more ecological perspective because they assess several EF components across different contexts (Toplak et al. 2013). Using ratings of EF in the context of daily activities has revealed the EF difficulties that are characteristic of ASD (Blijd-Hoogewys et al. 2014; Chan et al. 2009; Granader et al. 2014; Rosenthal et al. 2013; Smithson et al. 2013; van den Bergh et al. 2014) and that are related to communication skills in persons with ASD (Pugliese et al. 2015).

## Relation Between Informant Ratings of EF and Communication

One of the most commonly used informant ratings scale of EF for children and adolescents with and without ASD is the Behavior Rating Inventory of EF (BRIEF, Gioia et al. 2000), which assesses an informant's perspective on how well people do in different EF domains. The BRIEF consists of eight scales (inhibit, shift, emotional control, initiate, working memory, plan/organize, organization of materials, monitor), which comprise two broad indices: Behavioral Regulation, profiling the ability to shift and modulate emotions and behavior via appropriate inhibitory control; and Metacognition, referring to the ability to cognitively self-manage tasks and monitor performance. Metacognition, in particular, has been consistently found to be closely related to communication skills in youth with ASD (Berenguer et al. 2018; Gardiner and Iarocci 2017; Gilotty et al. 2002; Peterson et al. 2015; Pugliese et al. 2015; Torske et al. 2018).

Conversely, research examining the relations between individual BRIEF scales and communication skills has yielded mixed results. Deficits in working memory have been found to be associated with poorer expressive and receptive vocabulary (Akbar et al. 2013) and a poorer communication score from the vineland adaptive behavior scales (VABS) (Gilotty et al. 2002; Pugliese et al. 2015). In addition to deficits in working memory, Gilotty et al. (2002) and Pugliese et al. (2015) also reported that deficits in the initiate subscale were associated with a poorer VABS communication score. A longitudinal study found that the score on the monitor subscale at 8 years of age predicted the VABS communication score when the same children were about 13 years of age (Pugliese et al. 2016). One study found that all scales of the BRIEF were associated with communication from the Adaptive Behavior Assessment System (Peterson et al. 2015), whereas another study reported that only monitor and plan/organize scales approached significance in relation to the behavior assessment system for children (BASC) FC scores, likely due to insufficient power to detect small effects (Gardiner and Iarocci 2017). It is worth noting that the majority of the studies did not include all scales of the BRIEF in their analyses (e.g., Akbar et al. 2013; Berenguer et al. 2018; Torske et al. 2018) and used diverse measures of communication (e.g., VABS, Social Responsiveness Scale, Clinical Evaluation of Language Fundamentals, Adaptive Behavior Assessment System) making comparisons between studies challenging. To understand the reason for the inconsistent findings, it is important to include all individual scales of the BRIEF. Further, using individual scales of the BRIEF is important as composite indices may hide variation within the individual scales (Gardiner and Iarocci 2017) and it allows examination of the unique contribution of specific EF domains (Purglise et al. 2015), which then can be used to tailor communication interventions for children with ASD.

In addition to general communication skills, EF may also play an important role in conversational skills. In young children with and without ASD, performance-based measures of EF were positively associated with interpersonal interaction (i.e., joint attention; McEvoy et al. 1993). Furthermore, a few studies have established links between performance-based measures of EF and social communication in typically developing children. Blain-Brière et al. (2014) found that in preschoolers, better inhibition skills were associated with a decrease in talkativeness (i.e., refraining from providing more information than necessary). Moreover, the production of more fluid utterances, and better working memory skills were associated with the production of clearer utterances and more contingent answers. Rints et al. (2015) found that pragmatic rule knowledge, but not pragmatic language use in everyday contexts, was associated with inhibition in preschoolers. Another important aspect of communication, the ability to identify a referent in a clear and unambiguous manner, has also been linked to inhibition (Nilsen and Graham 2009). However, it is not known whether ratings of EF are associated with conversational skills in children with ASD as this is the first study, to our knowledge, to examine these associations.

## The Current Study

In the current study, we examine EF in relation to functional and pragmatic communication among school-aged children with ASD. As deficits in EF are more pronounced during childhood (Kanne et al. 2011; Rosenthal et al. 2013), assessment during middle childhood offers an ideal window into how EF and communication in children with and without ASD may be related. We examine associations between EF, FC, and conversational skills in children with ASD as compared to a group of typically developing (TD) children of comparable age, IQ, and maternal education (a proxy for socioeconomic status). Based on previous research, we expected that metacognition would be the strongest predictor of FC in children with ASD (Berenguer et al. 2018; Gardiner and Iarocci 2017; Gilotty et al. 2002; McLean et al. 2014; Pugliese et al. 2015; Torske et al. 2018). Further, as previous research has found mixed results regarding the relation between communication and specific scales of EF, we did not make any a priori hypotheses about the subscale that would be most strongly associated with FC. With regard to the relation between parent ratings of EF and verbal conversational skills, we did not make any predictions as the parent ratings of EF used in the current study provide different information on EF than previous research, which has used performance-based measures.

## Method

### Participants

A sample of 186 school aged children with and without ASD aged 6–13 years of age were selected from a larger study on social attention in ASD, including 92 with ASD ($M = 9.90$ years, $SD = 1.89$; male = 58) and 94 who were TD ($M = 9.48$ years, $SD = 1.70$; male = 75). The Wechsler Abbreviated Scale of Intelligence 2nd Edition (WASI-II; Wechsler 2011) was used to estimate cognitive ability (as indexed by the Full Scale IQ; FSIQ) and to ensure that there were no significant differences between groups on FS IQ (see Table 1 for full scale IQ scores). An additional 19 children with ASD were excluded due to an IQ standard score less than 75 because intellectual disability is a comorbid condition that needs to be considered separately in children with ASD. There were no significant differences between groups for age, IQ, maternal education. Consistent with the gender distribution characteristic of the disorder (Centers for Disease Control and Prevention, 2014), there was a significantly higher proportion of males in the ASD group. As expected,

**Table 1** ASD groups compared to TD groups on key demographic and dependent variables

| Demographic variables | M *(SD)* | | *t*-value/ $\chi^2$ | *p*-value | *r* (effect size) |
|---|---|---|---|---|---|
| | TD ($n = 94$) | ASD ($n = 92$) | | | |
| Chronological age (years) | 9.48 (1.70) | 9.90 (1.89) | – 1.59 | .115 | .35 |
| Range | 6.79–13.40 | 6.89–12.90 | | | |
| FSIQ | 106.44 (12.10) | 102.75 (14.81) | 1.86 | .064 | .14 |
| Range | 75–142 | 75–145 | | | |
| Maternal education | 3.99 (0.83) | 3.85 (0.90) | 3.22 | .543 | .23 |
| Range | 2–6 | 1–5 | | | |
| AQ | 16.02 (7.80) | 31.92 (6.34) | – 14.99 | < .001 | .74 |
| Range | 3–37 | 19–48 | | | |

Maternal education was coded categorically, and ranged from 1 (less than high school) to 5 (graduate degree); Family Income = 1 = < $20,000, 2 = $20–49,999, 3 = $50–79,999, 4 = $80–109,999; 5 = $110–139,999, 6 = > $140,000

*M* mean, *SD* standard deviation, *ASD* autism spectrum disorder, *TD* typically developing, *FSIQ* full scale IQ, *AQ* autism spectrum quotient child or adolescent score, with higher scores indicating more autistic traits children in the ASD group had a significantly higher number of autism symptoms, as assessed with the Autism Spectrum Quotient Child (AQ-Child; Auyeung et al. 2008) or the AQ-Adolescent (Baron-Cohen et al. 2006). The AQ-Child was scored in the same way as the AQ-Adolescent (possible total scores of 0–50) (Allison et al. 2012) and the distribution of AQ scores for the ASD group in this study was comparable to the high functioning ASD adult sample in the original publication of the AQ (Baron-Cohen et al. 2001). The mean of our ASD group was three points lower than the mean in the ASD sample published in the original AQ study and the standard deviation was the same. See Table 1 for all participant demographic characteristics.

## Diagnostic Confirmation

Children in the ASD groups received a standardized clinical diagnosis of ASD from a qualified pediatrician, psychologist, or psychiatrist associated with the provincial government funded autism assessment network, or through a qualified private clinician. All diagnoses were based on the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; APA 2000) using the Autism Diagnostic Interview–Revised (ADI-R; Rutter et al. 2008), and Autism Diagnostic Observation Schedule (ADOS; Lord et al. 1999).

## Procedures

Human ethics approval was received from the University Research Ethics Board (ID #1257). Parents gave informed written consent before competing behavior rating inventory of executive function (BRIEF) (Gioia et al. 2000), the behavior assessment system for children-second edition, parent rating scales (BASC-2 PRS), the multidimensional social competence scale (MSCS), the AQ, and a demographic form that included questions pertaining to maternal education. Children provided verbal assent and were administered the WASI-II.

## Measures

### Executive Function

The BRIEF is a parent based rating scale designed to measure children's general EF in social and behavioral contexts (Gioia et al. 2000). As noted, the BRIEF consists of eights scales, which comprise two broad indices: behavioral regulation index (BRI) and metacognition index (MCI). Respondents rate the frequency of behavior on a three points Likert scale (never, sometimes, often). Higher ratings are indicative of greater perceived impairment (Gioia et al. 2000). The measure has high internal consistency (alpha = .82–.98) and high 3-week test–retest reliability ($r$ = .72–.84; Gioia et al. 2000). The validity of this measure is supported by the correlations with other behavior rating measures (Mahone et al. 2002). In the current study, 42 parents of TD and 51 parents of children with ASD filled in the BRIEF.

During data collection, the BRIEF was replaced with the BRIEF2 (Gioia et al. 2015) as BRIEF forms were no longer available from the publisher. This revision has resulted in a reduced number of items (63 of the original 86 items). All Parent Form coefficient alpha values for index scores for the BRIEF2 were reported to fall above .90, with coefficients for individual scales ranging from .80 (Monitor) to .91 (Emotional Control) in the standardization sample (Gioia et al. 2015, p. 101). The test manual reports high 3 weeks test–retest reliability (mean $r$ = .79; range = .67–.92) (Gioia et al. 2015, p. 111). In the current study, 52 parents of TD and 41 parents of children with ASD completed the BRIEF2. After consulting with authors of the BRIEF2, we combined the BRIEF $t$-scores with the BRIEF2 $t$-scores due to their similarity (within 1–2 $t$-scores points of each other on average; Gioia et al. 2015, p. 112). The only exception to this was the Monitor scales because the BRIEF Monitor scale was separated into the BRIEF2 Self-Monitor scale and the BRIEF Task-Monitor Score. Thus, it was not appropriate to combine $t$-scores in this case. As suggested by authors of the BRIEF2, we summed the BRIEF2 Self-Monitor scale raw score with the BRIEF2 Task-Monitor scale raw score, so that we would have a similar score for the BRIEF Monitor Raw Score. As we are aggregating BRIEF scales and indices with corresponding BRIEF2 scales and indices, we will refer to this combined data as the BRIEF/2.

### Functional Communication

The BASC-2 (Reynolds and Kamphaus 2004) provided indices of adaptive behavior. The Parent Rating Scale (PRS) child (PRS-C; age 6–11 years) and adolescent (PRS-A; age 12–21 years) forms were used in this study. Each PRS item is rated on a four points scale and item raw scores are converted into standardized $t$-scores for interpretation. For the BASC-2 PRS-C and PRS-A forms, internal consistency reliability coefficients for the major composite scores ranged from .90 to .95 (Median = .94), and alpha coefficients for the individual scales ranged from .72 to .88 (Median = .84). The BASC-2 also provided a measure of FC and high scores on this scale indicate better FC skills. Raw scores are converted into standardized $t$-scores for interpretation.

### Verbal Conversation Skills

The MSCS is a 77 item, ordinally scaled (i.e., 1 = "not true or almost never true" to 5 = "very true or almost always true") quantitative assessment of the individual differences in social competence (i.e., strengths and challenges) among individuals with ASD (Yager and Iarocci 2013). Internal consistency reliability coefficients for the individual scales scores ranged from .84 to .94 (Mdn = .89). Convergent validity between the MSCS total score and the Social Responsiveness Scale (SRS) (Constantino and Gruber 2005) was significant for individuals with and without ASD, ($r = -0.89$, $n = 132$, $p < .001$) and within individuals with ASD ($r = -0.78$, $n = 87$, $p < .001$). The MSCS yields a total raw score with higher scores indicating better social competence. The scale items are classified into seven relatively distinct domains of social competence including social motivation, social inferencing, demonstrating empathic concern, social knowledge, verbal conversation skills, nonverbal sending skills, and emotion regulation. The verbal conversation skills domain score was used in the present study; items of this domain probe for one's sense of timing (e.g. "joining conversations without interrupting"), conversational topic management (e.g. "shifting conversations to topics of interest"), and turn-taking ability (e.g. "dominating conversations and talking "at" people"). The MSCS Verbal Conversation Skills raw score was used in all analyses with higher scores reflecting better conversation skills.

### Analysis

All data analyses were conducted using SPSS Statistics, Version 19. In the present study, only one univariate outlier (data point with a standardized score in excess of 3.29, $p < .001$) from the ASD group was found in the BASC FC score. The indices for validity were in the acceptable range; thus, the score was changed to one unit above the next most extreme score in the distribution (from 35 to 29; Tabachnick and Fidell 2007). All values of skew and kurtosis within each group were acceptable (i.e., − 2 to 2 are acceptable for normal univariate distribution, George and Mallery 2010). To compare BRIEF/2, BASC2, and MSCS scores between groups (children with ASD and TD children), a series of one way analyses of variance (ANOVAs) were conducted. Hierarchical multiple regression analyses were then conducted separately for each group with BASC-2 FC and MSCS verbal conversation skills scales as dependent variables. Consistent with previous research, IQ was entered in the first block (FSIQ T scores normed by sex and age), followed by BRIEF/2 composite indices (BRI, MCI). If the BRI or MCI indices significantly contributed to a model predicting FC or verbal conversation, a second set of regressions were then conducted including the scales of the significant BRIEF/2 index entered in step 2. All assumptions necessary for multiple regression analyses to be conducted and considered valid were met, and no outliers or influential cases were detected.

## Results

Table 2 presents the BRIEF/2, BASC2, and MSCS scale means and standard deviation scores between the TD and ASD groups. As expected, children with ASD received significantly higher scores on all scales of the BRIEF/2 compared to children without ASD, suggesting caregivers' perceptions of greater overall EF dysfunction in children with ASD. Similarly, children with ASD received significantly lower scores on the BASC-2 FC scale and MSCS verbal conversations skills scale than children without ASD, suggesting caregivers' perceptions of greater overall communication difficulty in children with ASD. Results of bivariate correlation analyses are shown in Table 3.

### Functional Communication

To gauge the contribution of FSIQ and BRIEF index scores on FC in TD children, a hierarchical regression was conducted with the BASC FC score as the dependent variable (see Table 4). The second step in the hierarchical regression, which included both BRIEF index scores, was statistically significant $R^2 = .47$, $F(2, 90) = 38.35$, $p < .001$, and accounted for an additional 45.1% of unique variance in FC above IQ. As expected, the MCI of the BRIEF made a significant contribution to the model; however, IQ and the behavioural regulation index (BRI) also contributed significantly to the model. As the BRI and MCI indices significantly contributed to the model predicting FC, a second hierarchical regression was conducted to assess the contribution of the individual EF scales to FC. All the BRI and MCI scales (e.g., Emotional Control, Inhibit, etc.) were included at Step 2, $R^2 = .60$, $F(8, 84) = 15.06$, $p < .001$ (see Table 4). As expected, working memory contributed significantly to the model. However, in contrast to what we predicted, inhibition did not contribute significantly to the model, yet, organization of materials and monitor did. These results suggest that fewer EF difficulties in these components of EF (working memory, organization of materials and monitor) were associated with better FC skills. To examine the possibility that the significant result for the monitor scale was obtained because raw scores were used instead of T scores, a similar post hoc hierarchical regression was conducted with FSIQ, sex, and age entered at Step 1. When the individual EF scales were included at Step 2, $R^2 = .60$, $F(8, 82) = 12.07$, $p < .001$, the monitor scale remained a significant univariate predictor($p = .01$).

For children with ASD, a similar hierarchical regression was conducted to examine the contribution of FSIQ and BRIEF index scores on FC with the BASC FC score as the

**Table 2** BRIEF/2, BASC-2, and MSCS descriptive statistics

| | M *(SD)* | | F | *p* | $\eta^2$ |
|---|---|---|---|---|---|
| | TD ($n=94$) | ASD ($n=92$) | | | |
| BRIEF/2 emotional control | 53.88 (13.36) | 65.30 (10.70) | 41.30 | <.001 | .43 |
| BRIEF/2 inhibit | 51.85 (12.37) | 65.74 (10.96) | 65.55 | <.001 | .51 |
| BRIEF/2 shift | 53.34 (12.80) | 71.85 (11.50) | 107.51 | <.001 | .61 |
| BRIEF/2 plan/organize | 53.88 (11.92) | 66.57 (10.54) | 58.98 | <.001 | .57 |
| BRIEF/2 working memory | 53.00 (12.52) | 65.59 (10.05) | 57.05 | <.001 | .56 |
| BRIEF/2 initiate | 53.55 (11.22) | 66.18 (10.38) | 63.47 | <.001 | .49 |
| BRIEF/2 organization of materials | 52.95 (10.17) | 59.66 (9.24) | 22.20 | <.001 | .41 |
| BRIEF/2 monitor raw score | 15.04 (4.76) | 19.75 (3.84) | 54.93 | <.001 | .48 |
| BRIEF/2 behavioral regulation index | 52.06 (12.87) | 68.55 (10.88) | 88.90 | <.001 | .57 |
| BRIEF/2 meta cognition index | 53.40 (12.02) | 66.33 (9.92) | 63.76 | <.001 | .59 |
| BASC-2 FC | 48.26 (10.31) | 35.36 (9.23) | 80.73 | <.001 | .66 |
| MSCS VCS raw score | 38.17 (8.29) | 25.98 (6.73) | 121.10 | <.001 | .81 |

*M* mean *t*-score unless otherwise indicated, *SD* standard deviation, *ASD* autism spectrum disorder, *TD* typically developing, BRIEF/2 behavior rating inventory of executive function and behavior rating inventory of executive function second edition with higher scores indicting high executive dysfunction; *Monitor Raw Score* BRIEF monitor raw score and BRIEF2 monitor (self monitor raw score & task monitor raw score summed together), *Meta Cognition Index* BRIEF meta cognition index and BRIEF2 cognitive regulation index, *BASC-2* behavior assessment system for children-second edition parent report scale, *FC* functional communication *t*-score with higher scores indicating better FC skills, *MSCS VCS* multidimensional social competence scale verbal conversation skills raw score with higher scores indicating better verbal conversation skills

**Table 3** Correlations between FSIQ, FC, VCS, BRIEF/2 Indices and Scales

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. FSIQ | | .13 | .04 | .02 | .07 | −.00 | .05 | −.18 | .00 | .07 | .05 | .19 | .03 |
| 2. FC | .49** | | .46** | −.61** | −.64** | −.55** | −.56** | −.60** | −.57** | −.66** | −.60** | −.39** | −.69** |
| 3. MSCS VCS | −.04 | .28** | | −.74** | −.62** | −.63** | −.69** | −.62** | −.60** | −.60** | −.57** | −.51** | −.59** |
| 4. BRIEF/2 BRI | −.04 | −.38** | −.51** | | .77** | .85** | .94** | .83** | .68** | .73** | .71** | .64** | .82** |
| 5. BRIEF/2 MCI | −.07 | −.56** | −.43** | .67** | | .57** | .79** | .65** | .94** | .94** | .90** | .84** | .87** |
| 6. BRIEF/2 EC | .03 | −.38** | −.36** | .76** | .53** | | .75** | .69** | .49** | .51** | .57** | .47** | .72** |
| 7. BRIEF/2 Inhibit | −.06 | −.33** | −.48** | .88** | .59** | .55** | | .71** | .71** | .76** | .67** | .70** | .79** |
| 8. BRIEF/2 Shift | .00 | −.40** | −.38** | .73** | .60** | .68** | .56** | | .60** | .60** | .66** | .46** | .70** |
| 9. BRIEF/2 P/O | −.13 | −.53** | −.37** | .55** | .91** | .44** | .47** | .48** | | .85** | .84** | .73** | .79** |
| 10. BRIEF/2 WM | −.17 | −.54** | −.39** | .60** | .88** | .42** | .54** | .54** | .73** | | .81** | .72** | .79** |
| 11. BRIEF/2 Initiate | −.05 | −.49** | −.35** | .52** | .85** | .46** | .41** | .50** | .74** | .74** | | .70** | .74** |
| 12. BRIEF/2 OM | .19 | −.33** | −.34** | .48** | .68** | .44** | .46** | .47** | .49** | .52** | .52** | | .70** |
| 13. BRIEF/2 MRS | .01 | −.37** | −.40** | .64** | .71** | .52** | .60** | .52** | .61** | .59** | .52** | .60** | |

*FSIQ* full scale IQ; *FC* functional communication *t*-score with higher scores indicating better FC skills, *MSCS VCS* multidimensional social competence scale verbal conversation skills raw score with higher scores indicating better verbal conversation skills; *BRIEF/2* behavior rating inventory of executive function and behavior rating inventory of executive function second edition with higher scores indicting high executive dysfunction, *BRI* behavioral regulation index, *MCI* meta cognition index; *EC* emotional control, P/O plan/organize, *WM* working memory, *OM* organization of materials, *MRS* monitor raw score

Typically developing children are reported in the upper right of the table ($n=94$), children with ASD are reported on in the lower left of the table ($n=92$)

dependent variable (see Table 5). The second step was significant, $R^2=.52$, $F(2, 88)=25.20$, $p<.001$, and accounted for an additional 50.2% of unique variance. Within this model, as expected, MCI made a significant contribution to the model, however, IQ also contributed significantly to the model. As the MCI index significantly contributed to the model predicting FC, a second hierarchical regression was conducted to assess the contribution of the individual

**Table 4** Hierarchical multiple regression predicting functional communication and verbal conversation skills for TD children

| Predictor | Functional communication | | | Verbal conversational skills | | |
|---|---|---|---|---|---|---|
| | *β* | *t* | *p* | *β* | *t* | *p* |
| BRIEF/2 index analysis | | | | | | |
| Step 1 | | | | | | |
| FSIQ | .13 | 1.22 | .226 | .04 | 0.41 | .682 |
| Step 2 | | | | | | |
| FSIQ | .17 | 2.14 | .035 | .07 | 0.94 | .349 |
| BRIEF/2 behavioral regulation index | −.26 | −2.18 | .032 | −.64 | −5.77 | <.001 |
| BRIEF/2 meta cognition index | −.45 | −3.73 | <.001 | −.13 | −1.15 | .251 |
| BRIEF/2 scale analysis | | | | | | |
| Step 2 | | | | | | |
| FSIQ | .11 | 1.45 | .150 | .03 | 0.39 | .695 |
| BRIEF/2 emotional control | −.15 | −1.12 | .264 | −.19 | −1.59 | .116 |
| BRIEF/2 inhibit | .14 | 0.86 | .393 | −.42 | −3.35 | .001 |
| BRIEF/2 shift | −.09 | −0.77 | .444 | −.20 | −1.70 | .093 |
| BRIEF/2 plan/organize | .13 | 0.80 | .429 | – | – | – |
| BRIEF/2 working memory | −.52 | −3.19 | .002 | – | – | – |
| BRIEF/2 initiate | −.10 | −0.65 | .520 | – | – | – |
| BRIEF/2 organization of materials | .26 | −2.12 | .037 | – | – | – |
| BRIEF/2 monitor raw score | −.44 | −2.82 | .006 | – | – | – |

*TD* typically developing, *BRIEF/2* behavior rating inventory of executive function and behavior rating inventory of executive function second edition with higher scores indicting high executive dysfunction, *FSIQ* full scale IQ, *Meta Cognition Index* BRIEF meta cognition index and BRIEF2 cognitive regulation index, *Monitor Raw Score* BRIEF monitor raw score and BRIEF2 monitor (self monitor raw score & task monitor raw score summed together)

**Table 5** Hierarchical multiple regression predicting functional communication and verbal conversation skills for children with ASD

| Predictor | Functional communication | | | Verbal conversational skills | | |
|---|---|---|---|---|---|---|
| | *β* | *t* | *p* | *β* | *t* | *p* |
| BRIEF/2 index analysis (model 1) | | | | | | |
| Step 1 | | | | | | |
| FSIQ | .49 | 5.37 | <.001 | −.04 | −0.40 | .692 |
| Step 2 | | | | | | |
| FSIQ | .46 | 6.18 | <.001 | −.07 | −0.74 | .463 |
| BRIEF/2 behavioral regulation index | −.13 | −0.14 | .893 | −.40 | −3.26 | .002 |
| BRIEF/2 meta cognition index | −.52 | −5.16 | <.001 | −.17 | −1.38 | .172 |
| BRIEF/2 scale analysis (model 2) | | | | | | |
| Step 2 | | | | | | |
| FSIQ | .48 | 5.92 | <.001 | −.06 | −0.66 | .501 |
| BRIEF/2 emotional control | – | – | – | −.07 | −0.52 | .603 |
| BRIEF/2 inhibit | – | – | – | −.38 | −3.27 | .002 |
| BRIEF/2 shift | – | – | – | −.12 | −0.90 | .373 |
| BRIEF/2 plan/organize | −.17 | −1.32 | .192 | – | – | – |
| BRIEF/2 working memory | −.14 | −1.11 | .269 | – | – | – |
| BRIEF/2 initiate | −.12 | −0.98 | .331 | – | – | – |
| BRIEF/2 organization of materials | −.19 | −1.85 | .067 | – | – | – |
| BRIEF/2 monitor raw score | −.01 | −0.14 | .892 | – | – | – |

*ASD* autism spectrum disorder, *TD* typically developing, *BRIEF/2* behavior rating inventory of executive function and behavior rating inventory of executive function second edition with higher scores indicting high executive dysfunction, *FSIQ* full scale IQ; *Meta Cognition Index* BRIEF meta cognition index and BRIEF2 cognitive regulation index, *Monitor Raw Score* BRIEF monitor raw score and BRIEF2 monitor (self monitor raw score & task monitor raw score summed together)

EF scales to FC. When the individual MCI scales (e.g., Plan/Organize) were included at Step 2, $R^2 = .55$, $F(5, 84) = 11.22$, $p < .001$, only the contributions of IQ was significant ($p > .10$) (see Table 5). To examine the possibility that the non-significant result for the monitor scale was obtained because raw scores were used instead of T scores, a similar post hoc hierarchical regression was conducted with FSIQ, sex, and age entered at Step 1. When the MCI scales were included at Step 2 $R^2 = .60$, $F(8, 80) = 7.95$, $p < .001$, the monitor subscale still failed to predict a significant amount of variance in FC ($p = .53$).

### Verbal Conversation Skills

To evaluate the contribution of FSIQ and BRIEF index scores on verbal conversation (VC) skills in TD children, a hierarchical regression was conducted with the MSCS VC skills score as the dependent variable (see Table 4). The second step in the hierarchical regression, which included both BRIEF index scores, was statistically significant ($R^2 = .55$, $F(2, 90) = 55.14$, $p < .001$), and accounted for an additional 55.0% of unique variance in FC above IQ. Only BRI made a significant contribution to the model. As the BRI index significantly contributed to the model predicting VC skills, a second hierarchical regression was conducted to assess the contribution of the individual EF scales to VC skills. When the individual BRI scales (e.g., Emotional control) were included at Step 2 ($R^2 = .43$, $F(3, 89) = 33.02$, $p < .001$), only the inhibition subscale was significant, such that fewer EF difficulties in this domain were associated with better VC skills (see Table 4).

For children with ASD, a similar hierarchical regression was conducted to investigate the contribution of FSIQ and BRIEF index scores on VC skills with the MSCS verbal conversation skills score as the dependent variable (see Table 5). The second step was also significant ($R^2 = .28$, $F(2, 88) = 16.95$, $p < .001$), and accounted for an additional 27.8% of unique variance above and beyond IQ. Only BRI emerged as a significant predictor in the model. As the BRI index significantly contributed to the model predicting VC skills, a second hierarchical regression was conducted to assess the contribution of the individual EF scales to VC skills. When the individual BRIEF BRI scales were included at Step 2 ($R^2 = .26$, $F(3, 87) = 9.88$, $p < .001$), only inhibit was significant, suggesting that better inhibition skills were associated with better verbal conversation skills (see Table 5).

## Discussion

In the current study, we focused on how parent-rated EF predicts different aspects of communication among elementary school age children with and without ASD. The primary goal of this study was to extend previous work by examining EF in relation to FC and conversation skills, that is, communication that goes beyond functional or instrumental goals and involves social goals such as sharing and reciprocating, in youth with ASD. Parent questionnaires of EF such as the BRIEF are considered ecologically valid assessments of the metacognitive knowledge and behavioural control skills that make up EF. These assessments can help clinicians and researchers identify areas of concern that pertain to the way children navigate day-to-day routines in their lives. These areas may then be amenable to targeted clinical interventions. As expected, we found that children with ASD were rated as demonstrating significantly more EF challenges when assessed with the BRIEF, on all summative indices and scales, compared to TD children who were not significantly different in terms of age, IQ, and maternal education. Consistent with previous research, we also found that children with ASD were rated as demonstrating significantly poorer FC and verbal conversational skills than their TD matched peers (Gardiner and Iarocci 2017; Yager and Iarocci 2013).

EF indices contributed to FC scores above and beyond IQ. For TD children, both metacognition and behavior regulation skills were associated with FC. Among children with ASD, metacognition skills, but not behavior regulation skills were most closely related to FC, which was consistent with our hypothesis. The results build on a growing literature suggesting that metacognition skills are very closely related to communication skills (receptive, expressive, and written) as measured using the VABS (Gilotty et al. 2002; McLean et al. 2014; Pugliese et al. 2015), and pragmatic skills (inappropriate initiation, stereotyped language, use of context, and non verbal communication) (Berenguer et al. 2018) in youth with ASD.

When metacognition and behavior regulation indices were broken down into specific components of EF, a different pattern of results emerged for TD children and children with ASD. For TD children, parent-reported problems with working memory, organization of materials, and monitoring were significant predictors of lower FC skills. These results are consistent with those of Gardiner and Iarocci (2017), who reported that better monitoring skills predicted better FC, with working memory skills approaching significance in predicting FC ($p = .09$). It is difficult to determine how generalizable our findings are as most studies in this area limited their sample to children with ASD (e.g., McLean et al. 2014; Pugliese et al. 2015), and studies that did include a group of TD children did not report on the relations between the BRIEF and communication in this group (Berenguer et al. 2018).

For children with ASD, the component scales of the MCI were not significantly associated with FC, which is consistent with the results from Gardiner and Iarocci (2017). The observed between-group differences suggest that different executive mechanisms are implicated in the FC of children with and without ASD, yet metacognitive skills were found to be important for both groups. These results also suggest that intervention approaches for children with ASD may need to address the child's ability to problem solve in a variety of contexts including metacognitive skills such as initiating tasks, organizing materials, monitoring, and problem solving in working memory.

In contrast to FC skills that had a distinct pattern of results for each group of children, children with and without ASD had a similar pattern of results for verbal conversation skills. For both of the groups, behavior regulation skills rather than metacognition skills was the stronger predictor of verbal conversational skills. This finding suggests that self -regulating behavior may be especially important to communicating when social goals such as sharing and reciprocating are needed.

Further, both parents of children with and without ASD reported that difficulties with inhibition were associated with lower verbal conversation skills. The children who have a hard time inhibiting impulses and turn-taking (e.g., interrupting others, blurting things out) during the elementary school years may be seen as having particularly poor verbal conversation skills. These results are consistent with studies using performance-based EF measures which have found better inhibition skills were associated with better pragmatic rule knowledge (Rints et al. 2015) and a decrease in talkativeness (Blain-Briere et al. 2014). The lack of behavioural self-regulation may reflect difficulties with thinking before acting and, possibly, a lack of social awareness of when it is appropriate to act (Blain-Briere et al. 2014). Nilsen and Graham (2009) argue that inhibition skills are required to suppress an egocentric interpretation of the situation, thus, these skills are important for referential communication. In addition, Jahromi et al. (2013) found that inhibition uniquely predicted emotion regulation in preschool children with and without ASD, and subsequently also predicted children's school engagement.

Identifying and addressing the particular EF difficulties that are implicated in the developing functional and social communication skills of elementary school age children with ASD may improve a child's social adaptive functioning (Gardiner et al. 2017). For many children with ASD who have average or above cognitive ability, language proficiency (e.g., adequate articulation, vocabulary and grammar skills) is not sufficient for social communication to emerge. These children frequently have difficulty applying their verbal skills in the service of functional and pragmatic goals of communication. Thus, interventions that focus on teaching knowledge about FC and conversation (e.g., social stories/sequences or scripts) may not fully address the social communication deficits of children with ASD. To improve social communication skills in the long term, these children are more likely to benefit from learning about how to strategically use and control or coordinate their skills/actions, that is, how and when to *use* the knowledge that they have. In this way, improving EF may be helping the children with the *how* of learning so that they can apply the process to many different contexts wherein communication is vital for social adaptation.

### Limitations

A few limitations of the current study are worth noting. First, our measures of EF, FC, and verbal conversation skills were completed by the same parent and our findings may be influenced to some extent by shared variance. All three measures, the BRIEF/2, BASC-2, and MSCS have teacher report versions so it may be useful to have future research examine whether the same associations would emerge across different contexts (i.e., home, school, community). Second, we limited our sample to children with ASD with average or above average IQ to address concerns regarding the influence of comorbid intellectual disability. However, it is possible that a different pattern of results would emerge in children with intellectual disability and ASD. Specifically for minimally verbal children with ASD, FC may take many forms including words, gestures, picture exchange systems, or assistive technology devices (Brady and Halle 1997). It would be useful to know whether EF processes are also implicated in the FC of children with ASD who are minimally verbal or nonverbal. Further, our sample consisted of a significantly higher proportion of males in the ASD group than the TD group. While this gender difference is consistent with the gender distribution characteristic of ASD, it is not known if similar results would be obtained in a sample of children with ASD that included more females. Third, we acknowledge that our final model with the ASD group included six predictors, which meant we were not able to detect small effects ($f^2 = .02$); however, post hoc power analyses showed we had sufficient power to detect medium effects ($f^2 = .15$, power = .77, Faul et al. 2007). Finally, this study used a cross-sectional design and, thus, we cannot make any claims about the direction of the relation between EF and FC and conversation skills. Longitudinal studies are necessary to better understand how EF and communication are related, the developmental changes in communication skills over time and, the optimal developmental periods for intervention.

## Conclusion

In a sample of children with and without ASD, we found that parent-rated EF processes accounted for additional variance, beyond IQ, in FC skills and verbal conversation skills. Specifically, for children with ASD, only metacognition skills were associated with FC, whereas behavioral regulation skills were associated with verbal conversation skills, with inhibition skills being the strongest contributor to this association. Thus, we suggest that by targeting EF implicated in social communication, cognitively able children with ASD may learn how and when to ***use*** their verbal skills—strategies that can be applied to many different communicative contexts.

**Acknowledgments** S.M.H. is currently supported by the BC Children's Hospital Research Institute (BCCHRI; University of British Columbia) and the Brain Canada and Kids Brain Health Network Developmental Neurosciences Research Training Award. G.I. was supported by a Michael Smith Foundation for Health Research (MSFHR) Scholar Award, a Social Science and Humanities Research Council grant and a Natural Sciences and Engineering Research Council grant. We are grateful to the youth and parents who participated and the many students who helped at various stages of this research.

**Author Contributions** SMH, UM, and GI formulated the research hypotheses. SMH conducted the data screening and analyses. SMH drafted the manuscript. UM and GI assisted with the introduction and discussion. All authors read and approved the final manuscript.

## Compliance with Ethical Standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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