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Executive functions and pragmatics in children with high-functioning autism

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Abstract

Children with deficits in executive functions (EFs) and impairments in pragmatic language have a range of cognitive and language difficulties that affect their literacy and educational achievements. As deficits in EFs and pragmatic impairments are characteristics of autism spectrum disorders, this study examined the associations between EFs and pragmatic skills in children with high-functioning autism (HFA). Fifteen children with HFA (5–9 years; $M = 7.44$, SD 1.21), matched to 15 typically developing peers on age, gender, and non-verbal intelligence participated in the study. Children completed a pragmatic language assessment protocol, and a rating scale of EFs was administered to parents. Our results point to two main findings: children with HFA presented pragmatic difficulties and EFs impairments when compared with typically developing peers; and, as shown by a significant indirect effect of group on pragmatics via EFs, the poor pragmatics skills of HFA children were associated with their EFs difficulties. These findings may be of clinical relevance for children with pragmatic impairments, such as autism spectrum disorders. Future studies are crucial to further investigate the relationship between impaired pragmatics and EFs.

Keywords Executive functions · Pragmatics · High-functioning autism · Autism spectrum disorders

Literacy was defined as "the ability to identify, understand, interpret, create, communicate and compute using printed and written materials associated with varying contexts" (United Nations Educational, Scientific, and Cultural Organization,

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UNESCO, 2004, p. 13). A foundational component to the effective acquisition and development of this ability is oral language (Button & Milward, 2005; Storch & Whitehurst, 2002). Indeed, children with poor oral language skills have poor literacy skills (Catts, Fey, Tomblin, & Zhang, 2002). An important but less extensively studied component of oral language is pragmatics, which can be defined as the appropriate use of language in social interactions (Cekaite, 2013). Research suggested that pragmatic skills impact the development of literacy (Coplan & Weeks, 2009; Troia, 2011). For example, pragmatic difficulties may play a key role in written performance when perspective taking is required, as in the case of writing a text for a specific audience (Carruthers & Smith, 1996; McTear & Conti-Ramsden, 1991). As higher cognitive processes, executive functions (EFs; also called executive control or cognitive control; Diamond, 2013) have been proposed to play a pivotal role in literacy as well as in specific components of oral language, such as pragmatics (e.g., Zelazo et al., 2003). For instance, Nilsen and Graham (2009) showed that inhibition plays an important role in children's ability to consider the perspective of the other. Although both pragmatics and EFs affect literacy, few research has explored the link between these variables. In this article, we aimed to shed light on the relationship between pragmatic language and EFs in children with high-functioning autism (who tend to display deficits in EFs and pragmatics; Bishop & Norbury, 2005; Norbury, Nash, Baird, & Bishop, 2004; Ozonoff, 2001; Reisinger, 2011; Schuh, 2012). Results may contribute to our understanding about the cognitive mechanisms underlying pragmatic language in typical and atypical populations, and support the development of fine-grained interventions to promote pragmatics and, ultimately, literacy development.

Autism spectrum disorder (ASD) is a group of neurodevelopmental disorders characterized by deficits in communication and social interaction, with restricted and repetitive patterns of behavior, interests, or activities (American Psychiatric Association, 2013). This disorder is characterized by a wide range of variability, from low-functioning autism to high-functioning autism (HFA). Individuals with low-functioning autism are severely affected presenting profound impairments and lower intellectual functioning than their peers. In comparison, individuals with HFA are characterized by higher verbal and intellectual functioning (e.g., Carpenter, Soorya, & Halpern, 2009). Individuals without intellectual disabilities are often referred to as having HFA (Baron-Cohen, 2000; Howlin, 2003).

A wide range of verbal language difficulties are reported in individuals with ASD, but a striking feature of this disorder is the presence of pragmatic language impairments (Ying Sng, Carter, & Stephenson 2018). Definitions of pragmatic language skills involve the appropriate use of language in social contexts to express communicative intentions as well as the ability to make inferences about social situations and manage discourse (Huang, 2017). Well-known pragmatic dimensions are irony, metaphor, and non-literal language, which require the integration of contextual information (e.g., beliefs and intentions) to understand intended meanings. Additionally, specific aspects of discourse and conversation, such as topic maintenance and coherence, are also pragmatic dimensions, because speakers have to follow the rules that are appropriate to the social context.

Therefore, understanding speakers' messages and intentions, in which context plays a major role, is a complex task (Schmid, 2012; Singer & Lea, 2012).

Importantly, difficulties in pragmatics can impact adult–child relations, students' socio-emotional well-being, interactions in educational settings, and students' literacy skills (e.g., Coplan & Weeks, 2009; Schalock, 1996; Troia, 2011). For example, pragmatic difficulties may impose severe constraints in the production of written language by affecting key ingredients in writing. Specifically, by their association with perspective taking, these difficulties can reduce audience awareness (Carruthers & Smith, 1996; McTear & Conti-Ramsden, 1991). Also, pragmatic impairments may interfere with discourse regulation and the use of figurative language, which helps authors to illustrate complex relationships between ideas, people, and things in novel and creative ways (Troia, 2011).

Research on pragmatics in ASD has mostly focused on specific aspects, like the understanding of irony (Wang, Lee, Sigman, & Dapretto, 2006), humor (Emerich, Creaghead, Grether, Murray, & Grasha, 2003), metaphors (Happé, 1995; Rundblad & Annaz, 2010), and idioms (Lee, Song, Ham, Song, & Cheon, 2015). Furthermore, several studies explored the perception of pragmatics, such as the recognition of emotions (Kuusikko et al., 2009; Loukusa, Mäkinen, Kuusikko-Gauffin, Ebeling, & Moilanen, 2014) and difficulties with verbal theory of mind (Durrleman & Franck, 2015).

Another core feature of individuals with ASD is an executive (dys)function (e.g., Hill, 2004; Rajendran & Mitchell, 2007), which has been an active area of research for this clinical population. Compared with typically developing peers, individuals with ASD have been shown to present difficulties in working memory (e.g., Barnard, Muldoon, Hasan, O'Brien, & Stewart, 2008), cognitive planning (e.g., Ozonoff et al., 2004), and set-shifting (e.g., Minshew, Muenz, Goldstein, & Payton, 1992; Ozonoff et al., 2004), as well as perseveration of behavior (i.e., continuing to perform actions that are no longer appropriate or relevant, given the context; e.g., Prior & Hoffmann, 1990). Thus, impairments in EFs could be a potential explanation for many features of ASD.

Interestingly, several authors suggested that deficits in EFs may be linked to pragmatic impairments. For example, in adults, pragmatic impairments, such as excessive talkativeness, topic shifting, and difficulties with indirect questions, were found in individuals after a pre-frontal brain injury, that typically involves disruption of EFs (e.g., Dardier et al., 2011; Douglas, 2010). In line with this evidence, EFs appear to be necessary for the typical functioning of pragmatic skills.

Many researchers suggest that deficits in EFs cause pragmatic language problems (e.g., Zelazo et al., 2003). Research also suggests that in typically developing children the development of pragmatic abilities is closely linked to other higher cognitive processes such as EFs. For instance, Nilsen and Graham (2009) showed that in typically developing 3–5 year olds, inhibition plays an important role in children's ability to consider the perspective of the other, probably because inhibition allowed children to restrain their own perspective and to be able to consider the other's viewpoint (Nilsen & Graham, 2009). Schuh (2012) found that typically developing children (aged 8–17 years) with higher working memory ability answered more accurately to their partner's request. Blain-Brière,

Bouchard, and Bigras (2014) showed that, for typically developing preschoolers, EFs contributed significantly more than IQ to pragmatic skills. Thus, EFs skills seem to underlie the development of pragmatic skills among typically developing children. Therefore, addressing the question whether EFs influence pragmatics, some researchers proposed EFs skills as a necessary component of pragmatic development.

However, other authors have explored the reverse pattern examining if language impairments can explain deficits in EFs (e.g., Akbar, Loomis, & Paul, 2013). For example, rules derived from language learning enable manipulation of higher cognitive processes via internal representations (Zelazo & Frye, 1998; Zelazo et al., 2003). In support of this view, longitudinal studies in typically developing children showed that early language markers seem to predict self-regulation and EFs (Kuhn, Willoughby, Wilbourn, Vernon-Feagans, & Blair, 2014); Petersen, Bates, & Staples, 2015).

Evidence for the link between deficits in EFs and pragmatic impairments was also found for atypical development. For example, difficulties in using the pragmatic component of oral language has been consistently observed in children with deficits in EFs, such as in Attention Deficit Hyperactivity Disorder (ADHD; Bruce, Thernlund, & Nettelbladt, 2006; Humphries, Koltun, Malone, & Roberts, 1994) and ASD (Bishop & Norbury, 2005; Norbury et al., 2004; Ozonoff, 2001; Reisinger, 2011; Schuh, 2012).

Although the association between EFs and pragmatic skills is suggested from the findings reported above, studies examining this relationship had a small sample size, lack of psychometric properties of the measurement tools, and disregarded important covariates, such as nonverbal intelligence (Matthews, Biney, & Abbot-Smith, 2018). Also, as far as we know, few authors have explored this relationship among children with atypical development. Nonetheless, the comparison between typically developing children and children who have neurodevelopmental disorders presents a unique opportunity to explore the links between developmental skills that may be less visible in typical development.

As deficits in EFs and pragmatic impairments are both characteristics of autism, this study explored the role of EFs abilities and pragmatic language skills in children with this disorder, specifically with HFA. This study is innovative because it uses informant questionnaires and observational protocols to evaluate EFs and pragmatic skills, respectively, in everyday contexts. In addition, as previous studies have shown that vocabulary and intellectual quotient may also be related to pragmatic skills (McDonald, 2000; Bonifacio et al., 2007; McKown, 2007), children with HFA constitute a specific clinical population that offers methodological advantages by separating the confounding cognitive issues seen in other atypical populations. Although cognitive issues were excluded through diagnosis, from previous studies on children with neurodevelopmental disorders it was not clear whether other variables influence the development of EFs and pragmatic (Bishop, Nation, & Patterson, 2014). Thus, it is also important to control covariates such as nonverbal intelligence and vocabulary. The following three questions guided the study:

1. Does HFA affect pragmatic skills and ratings of global executive functioning?
2. Do pragmatic skills correlate with global ratings of executive functioning in the HFA and typically developing groups?
3. Do ratings of executive functioning mediate the differences in pragmatic skills between the HFA group and the typically developing group, after controlling for important covariates (i.e., nonverbal intelligence and vocabulary)?

Method

Participants

Fifteen children (2 girls, 13 boys) with HFA (5–9 years; $M = 7.44$, SD 1.21), who met the DSM-5 criteria for Autism (American Psychiatric Association, 2013). The materials used for diagnostic purposes were the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) and the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 1989). Details about participants' characteristics are provided in Table 1. The group with HFA was matched to a typically developing (TD) group (n = 15) on chronological age ($M = 7.27$, SD 1.44), gender, and non-verbal intelligence (HFA: $M = 25.25$, SD 4.95; TD: $M = 24.00$, SD 4.23; assessed with Raven's Colored Progressive Matrices, RCPM; Raven, 1995; Simões, 2000). This matching eliminated nonspecific factors as performance explanations, such as intellectual disability. Additionally, there were no significant differences between groups for receptive vocabulary (HFA: $M = 121.44$, SD 33.70; TD: $M = 142.07$, SD 31.51; assessed with Peabody Picture Vocabulary Test, PPVT; Dunn & Dunn, 2007; Vicente, Sousa, & Silva, 2011). All participants were native speakers of European Portuguese with no visual or hearing problems according to parents and teachers/technician reports.

Table 1 Descriptive statistics for age, non-verbal intelligence, vocabulary, pragmatics, and executive functions of the participants in the high-functioning autism (HFA) and typically developing (TD) groups

	HFA ($n = 15$)			TD ($n = 15$)		
	M	SD	Range	*M*	SD	Range
Age	7.44	1.21	5–9	7.27	1.44	5–9
Nonverbal intelligence	25.25	4.95	17–32	24.00	4.23	17–32
Vocabulary	121.44	33.70	53–182	142.07	31.51	99–188
Pragmatics	17.40	10.32	0–30	29.80	0.41	29–30
Executive functions	63.96	11.97	49–88	50.40	9.06	40–66

Maximum score for nonverbal intelligence = 36. Maximum score for vocabulary = 228. Maximum score for pragmatics = 30. Maximum score for executive functions problems = 105

Materials

Control tasks (nonverbal intelligence and vocabulary knowledge)

Children were assessed with the Raven's Colored Progressive Matrices (RCPM) to control for nonverbal intelligence (Raven, 1995; Simões, 2000). This test provides a 36-item paper format, and, in each test item, participants are asked to point to the missing item that completes the pattern. Participants also completed the Peabody Picture Vocabulary Test (PPVT) to assess vocabulary knowledge (Dunn & Dunn, 2007; Vicente et al., 2011). The test consists of 228 items distributed across 19 itemsets. Most examinees respond by touching or pointing to the picture that best represents the meaning of a stimulus word verbally presented. Each item of RCPM and PPVT was scored as "correct" (1) or as "incorrect" (0), and higher scores suggest higher nonverbal intelligence and higher vocabulary knowledge, respectively.

Pragmatic skills

Participants were evaluated with the Pragmatic Protocol (Prutting & Kirchner, 1987), an observational measure of pragmatic skills for children aged 5 years and above and adults. The authors of the original version reported an inter-rater reliability of .94. To assess pragmatic language using this protocol, evaluators observed a social interaction/conversation during at least 15 min and they assessed verbal, paralinguistic, and nonverbal aspects. After this observation, two blind raters evaluated the 30 parameters divided into two main aspects: verbal (speech acts, topic selection and maintenance, turn-taking, lexical selection/use across speech acts, stylistic variations and intelligibility, and prosody) and nonverbal (kinesics and proxemics). Details about the pragmatic categories assessed by the Pragmatic Protocol are given in Table 2. These pragmatic behaviors were rated as appropriate, inappropriate, or not observed. Average reliability for judgments was 93.1%. Each category was scored as "appropriate" (1) or as "not appropriate" or "absent" (0), with higher scores meaning better pragmatic skills.

Executive functions

Parents completed the Behavior Rating Inventory of Executive Function (BRIEF)—Parent Form, a scale with 86 items with eight subscales of EFs domains (Gioia, Isquith, Guy, & Kenworthy, 2000; Barbosa, Teles, & Vicente, 2011). Measures of internal consistency ranged from .80 to .98 (Cronbach α coefficient measure), with test–retest reliability ranging from .76 to .88. Details about measures of EFs assessed by BRIEF are presented in Table 3. Each behavior was rated as never observed, sometimes observed, or often observed. The answer sheets use a three-point scale: "never observed" scored as 1, "sometimes

Table 2 Description of the pragmatic protocol (Prutting & Kirchner, 1987)

Pragmatic protocol—verbal aspects
A. Speech Acts
1. Speech act pair analysis (ability to take the speaker and the listener role proper to the context)
2. Variety of speech acts (includes acts like commenting, requesting, promising, and so forth)
B. Topic
3. Selection (selection of topics that are appropriate to the context)
4. Introduction (ability to introduce a new topic in the discourse)
5. Maintenance (a topic is coherently maintained throughout the discourse)
6. Change (changes of topic in the discourse)
C. Turn taking
7. Initiation (ability to initiate conversation by means of appropriate speech acts)
8. Response (involves the way in which the children, as a listener, responds to speech acts)
9. Repair/revision (ability to "repair" a conversation when a breakdown occurs and the ability to ask for a repair when a misunderstanding or ambiguity has occurred)
10. Pause time (between words or sentences, or the time it takes the child to answer a question)
11. Interruption/overlap (refers to cases in which the listener interrupts the speaker, or in which people talk at the same time)
12. Feedback to speakers (that can be given verbally with words or nonverbally through)
13. Adjacency (appropriate behavior would be if the participant maintains the appropriate length of pauses in the conversation to support the timing relationships between adjacent turns in the conversation; inappropriate behavior would be the lack of maintaining the appropriate pause length
14. Contingency (when the child produces utterances sharing the same topic as a preceding utterance and add information to the previous communicative act)
15. Quantity/conciseness (the child shouldn't provide too much or too little information)
D. Lexical selection/use across speech acts
16. Specificity/accuracy (ability to select lexical items of best fit to the topic)
17. Cohesion (recognizable unity or connectedness of the discourse)
E. Stylistic variations
18. The varying of communicative style (differences in vocabulary, syntactic structure, and vocal quality are appropriately used throughout the discourse depending on sociolinguistic factors)
F. Intelligibility and prosody
19. Intelligibility (clarity of the message)
20. Vocal intensity (loudness or softness of the message)
21. Vocal quality (resonance and/or laryngeal characteristics of the vocal tract)
22. Prosody (intonation, stress and pitch)
23. Fluency (the smoothness, consistency and rate of the message)
Pragmatic protocol—nonverbal aspects
G. Kinesics and proxemics
24. Physical proximity (distance between speaker and listener)
25. Physical contacts
26. Body posture
27. Foot/leg and hand/arm movements

Table 2 (continued)

Pragmatic protocol—nonverbal aspects
28. Gestures (movements supporting or replacing verbal behavior)
29. Facial expression
30. Eye gaze

Table 3 Description of BRIEF scales

Scale name	Description
Inhibit	Assesses inhibitory control and impulsivity
Shift	Evaluates the ability to move from one situation, activity, or aspect of a problem to another
Emotional control	Measures the ability to modulate and control emotional responses
Initiate	Assesses the ability to begin a task or activity and generate ideas, answers, or problem-solving strategies
Working memory	Measures the capacity to hold information in mind to achieves goals
Plan/organize	Evaluates the child's ability to manage task demand
Organization of materials	Measures organization of work, play, and storage spaces
Monitor	Assesses task-oriented monitoring or work-checking habits and self-monitoring or interpersonal awareness

observed" scored as 2, or "often observed" scored as 3, with higher scores indicating lower performance in EFs.

Procedure

Informed consent was obtained from participants' parents. For the pragmatic assessment, the task was a spontaneous conversation made for about 15 min with the child, and the evaluators asked participants about their daily routine activities or about a given topic like their favorite hobby. Control tasks (RCPM and PPVT) were administered after this conversation. Each child was assessed individually in a quiet room at their school, in their home, or at the University of Porto. Each individual assessment was administered in approximately 45 min. Parents were asked to individually complete the BRIEF questionnaire, which took approximately 10–15 min to complete.

Results

Research Question 1: group comparisons

Performance differences between the HFA and typically developing (TD) groups on the Pragmatic Protocol and the BRIEF were analyzed separately for overall scores (see Table 1 for descriptive statistics). In the Pragmatic Protocol, the difference between groups on overall mean score was significant: TD $M = 29.80$, SD 0.41;

HFA $M = 17.40$, SD 10.32; F (1, 28) = 22.35, $p < .0001$; $\eta_p^2 = 0.444$. In the BRIEF, the two groups also demonstrated differences in global score regardless of the individual BRIEF scale profile: TD $M = 50.40$, SD 9.06; HFA $M = 63.96$, SD 11.97; F (1, 28) = 11.270, $p = .002$; $\eta_p^2 = 0.305$. In both tests, the performance of the TD group was significantly better than that of the HFA group.

Research Question 2: correlations

To analyze the link between pragmatic impairments and EFs deficits, we computed Pearson correlations between variables. Again, we used the overall mean scores of the RCPM (nonverbal intelligence), PPTV (vocabulary knowledge), Pragmatic Protocol (pragmatic skills), and BRIEF (executive functions). For both groups analyzed together (i.e., HFA and TD children), we found a moderate significant correlation between the pragmatic skills and EFs ($r = -.555$, $p < .001$; see Fig. 1). The correlation showed that higher scores on the Pragmatic Protocol (i.e., better pragmatic skills) are correlated with lower scores on BRIEF (i.e., better performance in EFs). We also found a weak correlation between pragmatic skills and nonverbal intelligence and a moderate correlation between pragmatic skills and vocabulary knowledge (see Table 4 for details). When the groups were considered separately, the correlations lost statistical significance (cf. Table 5).

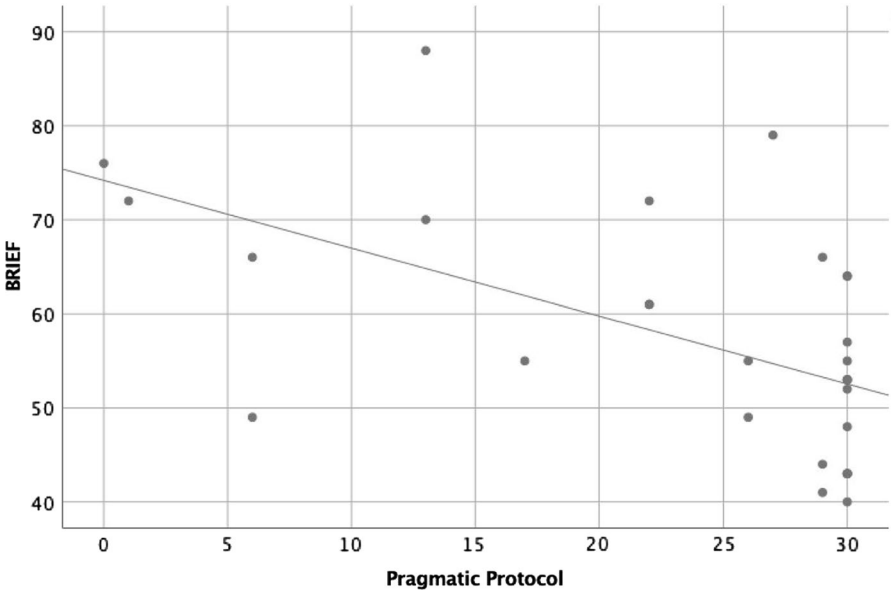

Fig. 1 Scatter plot displaying the correlation between Pragmatic Protocol and BRIEF

Table 4 Correlations between nonverbal intelligence, vocabulary, pragmatics, and executive functions

	Nonverbal intelligence	Vocabulary	Pragmatics	Executive functions
Nonverbal intelligence	–			
Vocabulary	.44*	–		
Pragmatics	.39*	.53**	–	
Executive functions	.09	− .16	− .55**	–

*$p < .05$; **$p \leq .01$

Table 5 Correlations between nonverbal intelligence, vocabulary, pragmatics, and executive functions by HFA and typically developing groups

	Nonverbal intelligence	Vocabulary	Pragmatics	Executive functions
Nonverbal intelligence	–	.55	− .25	.38
Vocabulary	.54	–	.66	.37
Pragmatics	.82	.46	–	.89
Executive functions	− .18	− .03	− .38	–

Correlations above the diagonal are for HFA children and below the diagonal are for typically developing children

Research Question 3: mediation analysis

To further explore the link between group (i.e., HFA and TD), EFs, and pragmatic impairments, we examined whether the group influenced pragmatics performance indirectly, through the EFs, after controlling for nonverbal intelligence and vocabulary knowledge. A mediation analysis was conducted, using the PROCESS macro for SPSS, version 3 (Hayes, 2018). We found a significant direct effect of group on pragmatics, $b = 9.53$, $t = -3.34$, $p < .003$. The indirect effect was tested through bootstrapping, using the bias-corrected method. Results revealed a statistically significant indirect effect of group on pragmatics via EFs. Specifically, for the HFA group, EFs difficulties were associated with poorer pragmatics skills, $B = -3.46$ (bootstrap standard error of 0.196), 95% CI [− 8.05; − 0.35].

Discussion

As EFs are involved in new and complex tasks, it seems valid to believe that these cognitive processes are involved in pragmatic behaviors. Thus, the goal of this study was to further our understanding about the link between EFs and pragmatics, investigating these abilities in children with HFA compared to typically developing peers, controlling for cognitive deficit (through diagnosis and nonverbal intelligence scores) and vocabulary knowledge. Fifteen children with HFA were matched to 15 typically developing peers on chronological age, gender, and non-verbal intelligence.

Nonverbal intelligence and vocabulary knowledge were controlled using the Raven's Colored Progressive Matrices (RCPM) and the Peabody Picture Vocabulary Test (PPTV), respectively. The Pragmatic Protocol was applied to evaluate pragmatic performance and the Behavior Rating Inventory of Executive Function (BRIEF)—Parent Form was used as an indicator of global executive abilities. Both measures are direct observational tools to evaluate EFs and pragmatic skills in natural contexts, which is an asset of this study in comparison to prior research.

The results pointed to two main findings. First, even though this population presents no primary cognitive disorder, children with HFA showed pragmatic difficulties and deficits in global executive functioning when compared with TD peers. As noted earlier, other studies have reported difficulties for autism on pragmatic domains (e.g., Emerich et al., 2003; Happé, 1995; Lee et al., 2015; Rundblad & Annaz, 2010; Wang et al., 2006) and on EFs assessments (e.g., Hill, 2004; Rajendran & Mitchell, 2007). Therefore, the current study confirms that pragmatic impairments and poor EFs are a characteristic of autism.

Second, our study showed that pragmatic skills correlate with global ratings of executive functioning. Importantly, our results also shed light on the complex interaction between these important domains. We have found a significant indirect effect of group on pragmatics via EFs, suggesting that deficits in EFs lead to poorer pragmatic skills specifically for children with HFA. Some theoretical approaches posit executive skills as a necessary component of language development in both typical (Baddeley, 2003) and atypical development (Pellicano, 2010). However, although many researchers suggest that deficits in EFs cause pragmatic language problems (e.g., Zelazo et al., 2003), some authors have explored the reverse pattern examining if language impairments can explain deficits in EFs (e.g., Akbar et al., 2013). Several arguments were used to support this claim, like internal speech being vital for regulating non-routine behaviors (Joseph, McGrath, & Tager-Flusberg, 2005; Ren, Wang, & Jarrold, 2016). Indeed, some studies analyzing the link between EFs and language abilities in autism suggested that language can play a mediating role in EFs (Apperly, Samson, & Humphreys, 2009; Joseph et al., 2005; Milligan, Astington, & Dack, 2007).

This concurrent association between EFs and pragmatics raises the possibility of a third variable that accounts for this relationship. From previous work on children with neurodevelopmental disorders, it was not clear whether other cognitive factors (such as nonverbal intelligence) are also at play, influencing the development of both EFs and pragmatics (Bishop et al., 2014). Our findings separate this confounding cognitive issue, first, by studying a neurodevelopmental disorder not characterized by intellectual disabilities (HFA) and, second, by controlling for nonverbal intelligence. Together, these characteristics of the present study allowed a stringent assessment of the link between EFs and pragmatics. A major conclusion arising from our findings is that EFs and pragmatics skills are impaired in children with HFA, but this impairment is not related to an intellectual deficit.

However, other general variables not here assessed can also account for the development of EFs and pragmatics and deserve further research attention. For instance, Im-Bolter, Johnson, and Pascual-Leone (2006) and Leonard et al. (2007) suggested that processing speed could account for the development of EFs and

language skills. In our opinion, this can also be true for pragmatics. Hypothetically, if common genetic mechanisms are involved in the development of pragmatics and EFs, it seems logical that problems on the development of the frontal lobes may impact brain regions that are important for both EFs and oral language components (Bishop et al., 2014). Indeed, a consequence of such shared mechanisms would be the comorbidity that is so frequently observed between disorders of EFs and pragmatics (like the associations reported by the present study).

Our pattern of results has implications for the development of interventions for children with pragmatic impairments, such as in ASD. Potentially, EFs training could enhance pragmatic skills. Enhancing EFs through a combination of techniques (such as direct and explicit verbal instruction, role-playing, and videotaping) might help to facilitate both EFs and pragmatic function. Furthermore, intervention to strengthen EFs and pragmatics could have the potential to achieve better outcomes. However, to gain better evidence for this direct relationship intervention studies are needed. As far as we know, there is no evidence showing that intervention focused on EFs have an impact on pragmatics or literacy skills.

It is important to underline the exploratory nature of the present study, and further research is needed to replicate this pattern of results. Given the overall conclusion that EFs are likely to be important for pragmatic skills, future research should specify the cognitive sub-processes linked to each pragmatic function that could explain atypical development, such as the relationship between: (a) inhibition and perspective taking; (b) working memory and the skill to answer contingently in a dialogue; or (c) cognitive flexibility and the process of repair of communication problems. Therefore, specific hypotheses about the specific cognitive mechanisms underlying the relationship between pragmatics and core EFs should be tested. This seems particularly important given the specificity of many cognitive-pragmatic associations (e.g., Ryskin, Benjamin, Tullis, & Brown-Schmidt, 2015). For instance, it has been suggested that inhibition allows children to inhibit their own perspective and to consider the viewpoint of others (Nilsen & Graham, 2009). Also, it has been shown that children with a higher working memory capacity answer more accurately to their partner's request (Schuh, 2012).

The current findings could also be enhanced by considering a larger sample of children with autism that could be divided into high/low function (the present study is limited at the highest levels of function). In addition, this study collected data from a single measurement in a single point in time, and it is not possible to study the effect of EFs on pragmatics development or the effect of pragmatics development on EFs. Thus, our data only indicates a concurrent relation between these two variables. Longitudinal studies using multiple time points are needed to explore the cognitive factors underlying the acquisition of pragmatics, and whether pragmatic skills may impact certain cognitive domains. Additionally, although the tools used to assess pragmatic skills and EFs were carefully selected and present several advantages over traditional measures often used in prior research (e.g., more realistic evaluation of children's abilities in natural and ecological contexts), the comparability of outcomes across all participants can be questionable. Despite these advantages, this kind of procedure leads to greater variability in the data when compared to more controlled methodological

procedures (e.g., Ambridge & Rowland, 2013). Therefore, in future research, as a complementary analysis, these procedures should be complemented with more controlled methodological procedures. Studies about the link between pragmatics and EFs are crucial for a full understanding of typical and atypical development, providing useful evidence for those with difficulties in pragmatics and EFs, and potentially related poor literacy achievements.

In conclusion, this study contributes to broadening our knowledge regarding oral language, which is a foundational component of the effective acquisition and development of literacy skills. Importantly, literacy is affected by oral dimensions of language (such as pragmatics) and by EFs. Ultimately, EFs and pragmatics need to be assessed and, potentially, facilitated for some students struggling to master literacy skills. Intervention programs need to focus on the dimensions that underpin individuals' impairments and disorders, and pragmatics and EFs could be important components. If a student is experiencing reading/writing difficulties, an integrated approach is vital, and an evidenced-based intervention should be chosen to fit the student's additional needs. In this endeavor, both teachers, neuropsychologists, psychologists, and speech and language therapists have key roles to play.

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Compliance with ethical standards

Conflict of interest The authors report no declarations of interest.

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