Communication abilities of children with ASD and ADHD

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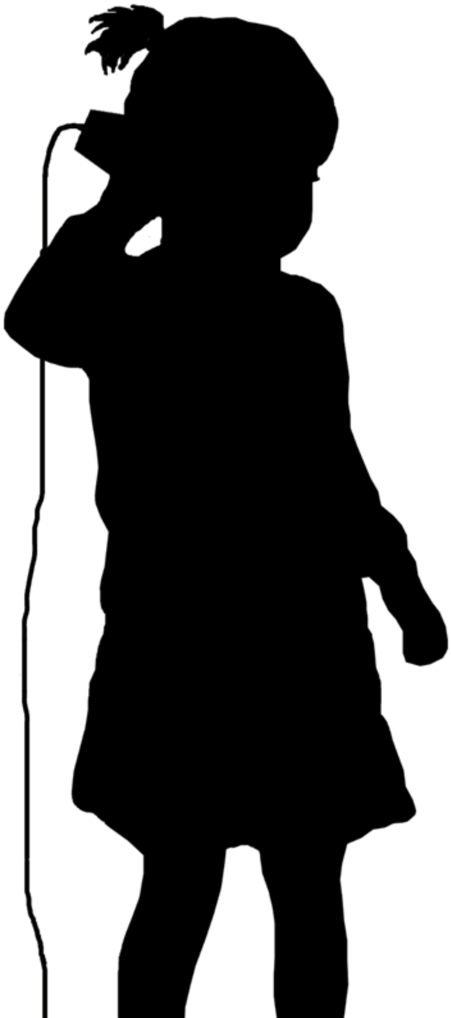
Theory of Mind deficits have different underlying mechanisms in children with ASD and ADHD

This chapter has been submitted as:
Kuijper, S. J. M., Hendriks, P., van den Wildenberg, W. P. M., Hollebrandse, B., Geurts, H. M., & Hartman, C. A. (2015). Theory of Mind deficits have different underlying mechanisms in children with ASD and ADHD.



Abstract

The social and communicative problems in children with autism spectrum disorder (ASD) are closely linked to Theory of Mind (ToM) deficits. Social problems in children with attention-deficit/hyperactivity disorder (ADHD) are also well documented, but there is dispute whether children with ADHD also have ToM deficits. The current study investigates ToM performance in ASD and ADHD and whether the same mechanisms underlie ToM performance in these groups. Children between 6 and 12 years old with ASD (n=46), ADHD (n=37), or typically developing age-matched controls (TD; n=38) were tested on ToM, working memory, response inhibition, and lexical-semantic verbal ability. ADI-R, ADOS, and PICS were administered to all children to confirm diagnosis.

Both children with ASD and children with ADHD performed worse on ToM tasks than TD children. Working memory and lexical-semantic ability mediated ToM deficits in children with ADHD, but not in children with ASD. Although both children with ASD and children with ADHD show deficits on ToM tasks, the mechanisms underlying their reduced performance differ. This suggests that the everyday social problems of children with ASD and ADHD may also have a different origin and that social skill interventions in children with ADHD may need to co-target verbal delays and aspects of executive functioning.

Introduction

Children with autism spectrum disorder (ASD) have deficits in social communication and reciprocal interaction. These problems in social functioning are closely related to their problems in Theory of Mind (ToM) (Tager-Flusberg, 2003). ToM is the ability to attribute mental states to oneself and others and to use these attributions to understand and predict the behavior of others. A cornerstone in ToM development is mastering of false beliefs (FB), in which a distinction is made between first-order and second-order FB. First-order FB involves the understanding that a person has his or her own beliefs and that these can be different from reality (e.g. “Pete thinks that it is raining”). Second-order FB involves the understanding of one person’s beliefs about another person’s thoughts (e.g. “Pete thinks that Mary believes that it is raining”). At around the age of 6 or 7, typically developing (TD) children are able to pass second-order FB tests (Perner & Wimmer, 1985), while children with ASD often show deficits (Baron-Cohen, 1985).

ASD and attention-deficit/hyperactivity disorder (ADHD) frequently co-occur (Rommelse, Franke, Geurts, Hartman, & Buitelaar, 2010; Ronald, Simonoff, Kuntsi, Asherson, & Plomin, 2008). Children with ADHD also exhibit problems in social functioning (Demopoulos, Hopkins, & Davis, 2013; Nijmeijer et al., 2008). This raises the question whether children with ADHD also show failures in ToM (Geurts, Broeders, & Nieuwland, 2010). Recent studies that investigated ToM performance in children with ADHD have shown mixed results. Some found impaired performance on ToM tasks in children with ADHD (Buitelaar, Van der Wees, Swaab-Barneveld, & Van der Gaag, 1999; Caillies, Bertot, Motte, & Raynaud, 2014; Mary et al., 2015) or found that stimulants improved ToM performance in children with ADHD (Maoz et al., 2014). Furthermore, children with ASD and children with ADHD performed similarly on recognition of facial emotions (Bühler, Bachmann, Goyert, Heinzel-Gutenbrunner, & Kamp-Becker, 2011). In contrast, other studies reported intact ToM performance in children with ADHD (Charman, Carroll, & Sturge, 2001; Dyck, Ferguson, & Shochet, 2001; Sodian & Hülsken, 2005; Yang et al., 2009) or at risk of ADHD (Perner, Kain, & Barchfeld, 2002). Thus, it is still unclear at this point whether children with ADHD have ToM impairments.

Successfully passing a standard FB test not only requires ToM, but also executive functioning (EF) abilities, such as inhibition and working memory (Hughes, Dunn, & White, 1998; Perner & Lang, 1999; Sodian & Hülsken, 2005; Yang et al., 2009). To successfully pass a FB task participants need to inhibit reference to the real state of affairs in favor of reference to someone’s FB about the state of affairs (Sabbagh, Moses, & Shiverick, 2006). Furthermore, successful performance on FB tasks requires that one must simultaneously hold in mind the real state of affairs and others’ beliefs about the state of affairs. Particularly in second-order FB tasks working memory is taxed, as it requires formulating an answer on the basis of a second person's belief about a third person's belief, while keeping in mind one's own belief about the state of affairs.

In addition to these two EF abilities, verbal ability may underlie ToM performance. A meta-analysis showed a significant relation between verbal ability and FB understanding in TD children (Milligan, Astington, & Dack, 2007). One type of verbal ability found to correlate with FB performance is lexical-semantic ability, the understanding of word meanings (Astington & Baird, 2005; Carlson, Moses, & Claxton, 2004). In addition to inhibition and working memory problems (Geurts, Verté, Oosterlaand, Roeyers, & Sergeant, 2004; Nydén, Billstedt, Hjelmquist, & Gillberg, 2001), children with ASD and children with ADHD show delays in lexical-semantic ability (Gremillion & Martel, 2012; Lord & Paul, 1997).

To what extent inhibition, working memory and lexical-semantic ability problems might underlie ToM performance of children with ASD and children with ADHD is as yet unclear. If children with ADHD show similar deficits in ToM as children with ASD, this does not necessarily imply that the same mechanisms underlie these problems in both groups. Inhibitory control was found to be related to ToM performance in children with ADHD (Mary et al., 2015), but did not account for group differences in ToM between ASD and TD (Yang et al., 2009). Whether working memory and lexical-semantic ability underlie ToM performance in children with ASD or with ADHD has not been investigated so far.

This study aims to enhance our understanding of the mechanisms underlying ToM impairment in children with ASD and ADHD. Firstly, we determine the extent to which problems in first-order and second-order FB understanding are present in children with ASD and children with ADHD. We hypothesize that children with ADHD show impaired performance on false belief tasks, as do children with ASD. Secondly, we investigate whether inhibition, working memory and lexical-semantic ability mediate ToM-task performance in ASD and ADHD.

Method

Participants

In total 127 children were tested (52 with ASD (7 girls), 37 with ADHD (6 girls) and 38 TD children (13 girls)), ranging in age from 6;1 to 12;10 (M=9;1, SD=1;9). IQ was assessed by two subtests (Vocabulary and Block Design) of the Dutch Wechsler Intelligence Scale for Children (WISC-III NL (Kort et al., 2002)). Table 1 provides the mean scores per participant group on the diagnostic instruments, IQ subtests, and the tasks to assess lexical-semantic ability, response inhibition, and working memory.

ASD

Children in the ASD group were diagnosed with autism (N=10), PDD-NOS (N=34) or Asperger's Syndrome (N=8) by clinicians on the basis of the DSM-IV-TR criteria. Furthermore, both the ADI-R (Rutter, Le Couteur, & Lord, 2003) and the ADOS (Lord, Rutter, DiLavore, & Risi, 1999) (along with the PICS, see below, to assess comorbid ADHD) were administered by trained psychologists. Children were included in the ASD group when they met ADOS criteria for ASD or autism and/or ADI-R criteria for autism or ASD (cf. Risi et al.'s (2006) criteria). Four children from the ASD group (2 diagnosed with PDD-NOS, 2 with Asperger's Syndrome) were excluded from further analysis, since they did not meet these criteria, leaving 48 children in the ASD group.

ADHD

Children in the ADHD group were diagnosed with ADHD-combined type (N=19), ADHD-Predominantly Hyperactive-Impulsive type (N=12) or ADHD-Predominantly Inattentive type (N=6) by clinicians on the basis of the DSM-IV-TR criteria. Furthermore, both the Parent Interview for Child Symptoms (PICS (Ickowicz et al., 2006)) and the Teacher Telephone Interview-IV (TTI-IV (Tannock, Hum, Masellis, Humphries, & Schachar, 2002)) (along with ADI-R and ADOS) were administered by trained psychologists. Six children with ADHD lacked TTI information. Four of them already scored above the cut-off for ADHD based on parent information alone. The remaining two children scored one point below the cut-off for ADHD. Since these children scored comparable on the PICS to the other children in the ADHD group (for whom TTI scores combined with their PICS scores exceeded the cut-off point), we included them in this study.

TD

Children in the TD group had not been diagnosed with ASD or ADHD. The ADOS, ADI-R and PICS were administered by trained psychologists in this group as well. None of the children scored above the cut-offs for ASD or ADHD described above.

Materials

Verbal FB

We used seven stories from the verbal FB task from Hollebrandse, Van Hout, and Hendriks (2014). Each story was accompanied by four pictures, presented one by one on a computer screen. In contrast to other FB tasks that only contain one or two stories with second-order FB questions (Buitelaar et al., 1999; Caillies et al., 2014; Sodian & Hülsken, 2005), this task provides a more valid estimate of children's FB performance and adds variation in performance among children. The stories were modeled after the original FB "ice cream van story" by Perner and Wimmer (1985). See Appendix 1, for more information about this task, along with an example story. Two dependent measures were calculated: mean accuracy on the second first-order

FB question (verbal first-order FB) and mean accuracy on the second-order FB question (verbal second-order FB).

Low-verbal FB

The low-verbal FB task (Hollebrandse et al., 2014) consisted of eight short movies, in which objects were manipulated. The task was presented in two blocks with a short break in between. The first part contained four movies testing first-order FB; the second part consisted of four movies testing second-order FB. See Appendix 2 for more information about this task, along with storyboard of a movie. Two dependent measures were calculated, both derived from the second-order movies: mean accuracy on the first-order FB question (low-verbal first-order FB) and mean accuracy on the second-order FB question (low-verbal second-order FB).

Response inhibition

Response inhibition was tested with a Stop Task adopted from Van den Wildenberg and Christoffels (2010) based on the stop-signal paradigm (Logan & Cowan, 1984). The Stop Signal Reaction Time (SSRT) (Band, Van der Molen, & Logan, 2003) was calculated as a measure of response inhibition. A description of the task is given in Appendix 3.

Working Memory

Working memory was tested with an n-back task (see Owen, McMillan. & Laird, 2005) including three experimental conditions: 0-back (baseline), 1-back, and 2-back. The total numbers correct on the 2-back condition was calculated as a measure of working memory (WM). The working memory task is more extensively described in Appendix 4.

Lexical-semantic ability

The Peabody Picture Vocabulary Test-III-NL (PPVT (Dunn & Dunn, 1997)) was administered to assess children's lexical-semantic ability. This standardized test requires the child to point to one of four pictures when hearing a word read by the experimenter. Raw scores on the PPVT were used in analyses.

Procedure

Children and their parents were recruited by brochures on schools and in outpatient clinics for child and adolescent psychiatry in Groningen. They took part in a larger study on communication problems in ASD and ADHD and came to the lab together. The parents of participating children signed for informed consent. Children were tested individually on a single day in a quiet testing room with two experimenters present. After each task children had a short break.

The order of the verbal and low-verbal FB tasks was counterbalanced over participants. The response inhibition task took place before the FB tasks and the working memory task after the FB tasks, or vice versa. Two children (ASD) conducted half of the verbal ToM task and were removed from further analysis. Two children (1 ASD; 1 ADHD) did not finish the n-back task and were removed from analyses including the n-back task. One of them (ADHD) and one other child (ADHD) were not able to complete the Stop task and consequently were excluded from analyses involving this task.

Data analyses

To test ToM performance in children with ASD and children with ADHD, firstly we carried out a multivariate multiple regression analysis. Contrasts between diagnostic groups and controls (ASD vs TD and ADHD vs TD) were dummy-coded and included as independent variables in the analysis. The mean percentages correct on the four FB conditions were normalized using an arcsine transformation and included as dependent variables.

We then carried out a series of multivariate multiple regression analyses to explore the effects of relevant parameters derived from the Stop task (SSRT), n-back task (WM) and the PPVT on the association between ASD and ToM performance, and between ADHD and ToM performance. Each parameter was studied separately to determine its contribution to predicting ToM performance. Subsequently, we tested whether the association between ASD and ToM, and between ADHD and ToM, was mediated by SSRT, WM, and PPVT, respectively. This was done for each FB condition, using Hayes' (2012) PROCESS macro for SPSS with 10.000 bootstrap samples and testing at a 95% confidence interval.

Finally, we simultaneously entered those parameters for which mediation was found in a regression model to determine their combined effect on ToM performance. Again, mediation of this combination of parameters in the relation between ASD-ToM and ADHD-ToM was investigated using Hayes' (2012) macro.

Results

Descriptives

Group means and standard deviations for age, IQ, clinical interviews, PPVT, n-back, and Stop task can be found in Table 1.

Testing Theory of Mind in ASD and ADHD

We plotted accuracy on the different FB conditions for the three groups (Figure 1). Multiple multivariate regression analysis indicated that both children with ASD (F (4,115) =

Table 1 Means and Standard Deviations per Group

	ASD (*n* = 46)		ADHD (*n* = 37)		TD (*n* = 38)		Bonferroni corrected post hoc analyses
	M	(SD)	M	(SD)	M	(SD)	
% Male	88		84		66		
Chronological Age	9;4	(1;10)	8;9	(1;7)	9;0	(1;9)	-
Mental Age	9;1	(2;8)	8;2	(1;11)	9;10	(2;3)	ADHD<TD**
ADI-R[a]							
Social Interaction	16.74	(6.09)	4.51	(4.07)	1.82	(3.09)	ASD***>ADHD>TD*
Communication	12.93	(4.24)	3.97	(2.66)	1.34	(1.55)	ASD***>ADHD>TD**
Stereotyped Behavior	4.33	(2.58)	1.41	(1.54)	0.32	(0.66)	ASD***>ADHD>TD*
Behavior < 3 yr	3.00	(0.99)	1.49	(1.52)	0.13	(0.41)	ASD***>ADHD>TD***
ADOS module 3[b]							
Communication	2.82	(1.48)	1.06	(0.92)	0.53	(0.76)	ASD***>ADHD,TD
Social interaction	7.53	(3.18)	2.56	(1.81)	1.50	(1.72)	ASD***>ADHD,TD
Com+Soc	10.36	(4.29)	3.61	(2.36)	2.03	(1.99)	ASD***>ADHD,TD
RRB	1.13	(1.24)	0.28	(0.57)	0.16	(0.44)	ASD***>ADHD,TD
Social Affect	9.29	(4.27)	2.83	(2.20)	1.74	(2.02)	ASD***>ADHD,TD
SA+RRB	10.42	(4.74)	3.11	(2.21)	1.89	(2.15)	ASD***>ADHD,TD
PICS[c]							
ADHD inattention	2.26	(2.10)	3.54	(2.19)	0.11	(0.39)	ADHD**>ASD>TD***
ADHD hyp/imp	1.93	(1.93)	5.11	(2.51)	0.29	(0.57)	ADHD***>ASD>TD***

	ASD (n = 46)		ADHD (n = 37)		TD (n = 38)		Bonferroni corrected post hoc analyses
	M	(SD)	M	(SD)	M	(SD)	
TTI[d]							
ADHD inattention	-	-	4.65	(2.18)	-	-	n.a.
ADHD hyp/imp	-	-	5.58	(2.64)	-	-	n.a.
WISC-III							
Block Design	9.85	(3.65)	8.35	(2.98)	11.16	(3.23)	ADHD<TD**
Vocabulary	8.89	(3.26)	9.49	(2.09)	11.82	(2.51)	ASD***, ADHD**<TD
Estimated Full scale IQ	96.38	(17.34)	93.44	(12.67)	109.02	(13.64)	ASD**, ADHD***<TD
PPVT							
WBQ	106.00	(15.12)	100.22	(12.49)	108.84	(10.72)	ADHD<TD*
Raw	115.89	(19.44)	105.81	(12.20)	116.32	(16.16)	ADHD*<TD, ASD
n-Back Task Correct 2back	39.07	(7.96)	38.19	(7.45)	41.77	(5.28)	-
Stop Task SSRT	260.09	(96.84)	254.84	(94.25)	256.74	(77.59)	-

* = $p \leq .05$; ** = $p \leq .01$; *** = $p \leq .001$; - = non-significant; n.a. = not applicable

[a] Five children in the ADHD group scored above the cut-off for ASD on the ADI-R (on the basis of Risi et al.'s criteria (2006))

[b] Two children in the ADHD group scored above the ADOS criteria for ASD

[c] Seven children in the ASD group scored within our criteria for ADHD on the PICS (above or one point below the cut-off on the PICS)

[d] TTI-scores were only available for 31 children in the ADHD group

5.03, $p < .01$, $\eta_p^2 = .15$) and children with ADHD (F (4,115) = 3.52, $p = .01$, $\eta_p^2 = .11$) performed worse than TD children on the four FB conditions. Follow-up univariate analyses revealed that the ADHD group scored significantly lower than the TD group on all four conditions (verbal FB1: *b* = -.21, *SE* = .068, *p* = .002; verbal FB2: *b* = -.33, *SE* = .12 *p* = .006; low-verbal FB1: *b* = -.18, *SE* = .077, *p* = .02; low-verbal FB2: *b* = -.37, *SE* = .015, *p* = .02) and that the ASD group performed worse than the TD group on both verbal conditions and on the low-verbal first-order FB condition (verbal FB1: *b* = -.19, *SE* = .064, *p* = .005; verbal FB2: *b* = -.34, *SE* = .11 *p* = .002; low-verbal FB1: *b* = -.18, *SE* = .073, *p* = .01). Children with ASD did not differ from TD children on low-verbal second-order FB (*b* = -.01 *SE* = .14, *p* = .92).

Exploration of mechanisms

Having established that on average both children with ASD and children with ADHD showed ToM impairments, we next investigated whether working memory, response inhibition and lexical-semantic ability mediated the association between the presence of ASD or ADHD and ToM performance.

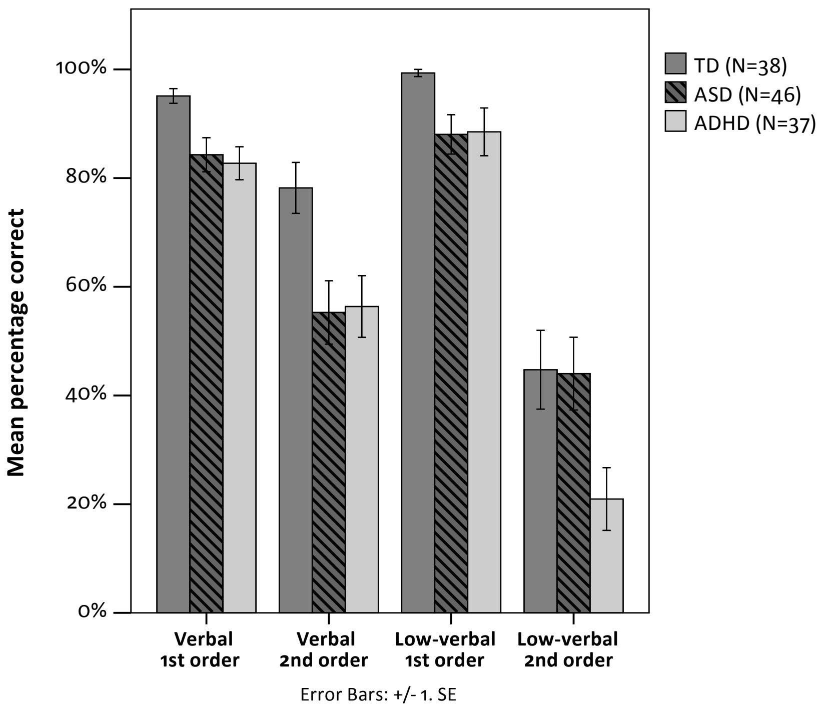


Figure 1 FB accuracy per group and per condition

Working Memory

Adding WM to the multivariate model, the association between ADHD and ToM performance became statistically insignificant (F (4,112) = 2.0, p = .07, η_p^2 = .07), while the relation between ASD and ToM persisted (F (4,112) = 4.05, p < .01, η_p^2 = .13). This suggests that in particular the ADHD-ToM association may be mediated by working memory. Bootstrap analyses testing this, using Hayes' PROCESS macro, indicated significant mediation of working memory between ADHD and all four FB conditions (verbal FB1: b = -.055, SE = .026, p < .05; verbal FB2: b = -.059, SE = .034 p < .05; low-verbal FB1: b = -.056, SE = .031, p < .05; low-verbal FB2: b = -.076 SE = .037, p < .05). In line with the multivariate effect, working memory did not mediate between ASD and ToM on any of the four FB conditions.

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Response inhibition

Multiple multivariate regression analysis showed that SSRT did not predict ToM performance (F (4,112) = .31, p = .87, η_p^2 = .01) and left the significant associations between ASD and ToM (F (4,112) = 4.93, p < .01, η_p^2 = .15) and between ADHD and ToM (F (4,112) = 3.17, p < .05, η_p^2 = .10) intact.

Lexical-semantic ability

With PPVT scores added in the multiple multivariate regression analysis, the association between ADHD and ToM disappeared (F (4,114) = 1.73, p = .15, η_p^2 = .06), while the relation between ASD and ToM remained significant (F (4,114) = 5.46, p < .001, η_p^2 = .16). This finding suggests that the association between ADHD and ToM may be mediated by lexical-semantic ability. Bootstrap analyses testing this showed significant mediation of lexical-semantic ability between ADHD and all FB conditions (verbal FB1: b = -.082, SE = .030, p < .05; verbal FB2: b = -.14, SE = .054, p < .05; low-verbal FB1: b = -.042, SE = .022, p < .05; low-verbal FB2: b = -.21, SE = .070, p < .05). In line with the multivariate effect, lexical-semantic ability did not mediate between ASD and ToM performance.

Combining cognitive mechanisms

A multivariate multiple regression analysis with both PPVT and WM, and the dummy-coded diagnostic groups as predictors of the four FB conditions, removed the association between ADHD and ToM (F (4,111) = 1.46, p = .22, η_p^2 = .05), but left that between ASD and ToM intact (F (4,111) = 4.52, p < .01, η_p^2 = .14). Simultaneously analyzed, both cognitive mechanisms were significantly related to ToM (WM (F (4,111) = 3.25, p < .05, η_p^2 = .11); PPVT (F (4,111) = 9.69, p < .001, η_p^2 = .26)). Bootstrap results indicated significant mediation of working memory and lexical-semantic ability between ADHD and the four FB conditions (verbal FB1: b = -.091, SE = .033, p < .05; verbal FB2: b = -.14, SE = .056, p < .05; low-verbal FB1: b = -.061, SE = .033, p < .05;

low-verbal FB2: $b = -.20$, $SE = .073$, $p < .05$). In line with the multivariate effect, no mediation was found between ASD and ToM performance.

Discussion

The first aim of this study was to establish whether children with ADHD fail on ToM tasks, like children with ASD. Our findings show that on average both the ADHD group and the ASD group show impairments on FB tasks. This confirms initial findings on second-order FB based on a small group of children with ADHD (Buitelaar et al., 1999) or on ToM scores derived from a task with only two second-order FB questions (Caillies et al., 2014). Our findings also partly corroborate a recent study by Mary et al.(2015) on ADHD (but not ASD), who reported impaired ToM performance on a faux pas task. Their study and our study converged in showing that response inhibition (in our study, stop task; in their study, go-no go task) has no role in second-order ToM performance. They further showed that cognitive inhibition (or interference control, based on the Stroop task) mediated the relation between ADHD and ToM, while we showed mediation effects of working memory. Note that interference control and working memory are strongly related (Kane & Engle, 2003; Palladino & Ferrari, 2013) and perhaps difficult to disentangle. Together these results show that ToM performance of children with ADHD is associated with working memory and/or interference control as well as lexical-semantic ability (Mary et al., 2015), but not with response inhibition.

Given our findings, it follows that children with ADHD may not have a genuine ToM impairment. Rather they seem to have difficulty in goal-directed processing of large amounts of verbal information. This may also explain earlier findings (Charman et al., 2001; Dyck et al., 2001) that children with ADHD show no impairments on Happé's (1994) Strange Stories Task and with other studies that did not find difficulties on first-order FB in the ADHD group (Mary et al., 2015; Yang et al., 2009). In these tasks, the processing demands of maintaining relevant information while ignoring irrelevant information are much lower than in second-order FB tasks. Second-order FB tasks are much more elaborate, as is the amount of verbal information that needs to be processed as the story unfolds.

The present study, therefore, yields insights in the overlap and differences between ASD and ADHD. Although resulting in similar performance on ToM tasks, the ToM deficit in ASD seems primary, while it is secondary to verbal and EF problems in ADHD. This suggests that the social difficulties both group encounter (Nijmeijer et al., 2008) may also have a different origin. Our findings have important consequences for both research and practice. For example, based on the at that point available literature we posited that ToM impairments may be an endophenotype common to both ASD and ADHD, potentially useful for furthering our neurobiological understanding of their overlap (Rommelse, Geurts, Franke, Buitelaar, & Hartman, 2011). Yet the present mechanistic study on ToM in ASD and ADHD and that by Mary et al. (2015) suggest that this may not be so. Refinement of what is common and what is unique to ASD and ADHD is also useful for those with an ASD or ADHD diagnosis. For example, intervention programs for children with ADHD to enhance social skills may need to be adapted towards the specific needs of children with ADHD (De Boo & Prins, 2007). Our findings suggest that a focus on improvement of verbal delays and aspects of executive functioning may be useful to enhance the social skills in this group.

Note that we, like others (Ozonoff & Strayer, 2001; Pennington & Ozonoff, 1996; Williams, Goldstein, Carpenter, & Minshew, 2005), do not find group differences in verbal working memory between children with ADHD and TD children. Nonetheless, ToM performance is mediated by working memory in the ADHD group. This illustrates the heterogeneity of ADHD (Sonuga-Barke, 2002). That is, deficits in working memory are found in some, but not all children with ADHD, and we show that these deficits are related to their performance deficits on the ToM task. The heterogeneity of ASD and ADHD is also reflected in ToM performance. Intact ToM performance has been reported for children with Asperger's Syndrome (Bowler, 1992) and children with high-functioning autism (Scheeren, De Rosnay, Koot, & Begeer, 2013). The subgroup of children (n=6) diagnosed with Asperger's Syndrome in our study indeed performed well on the ToM tasks (percentages correct above 92% on all four FB conditions). Thus, although we find that children with ASD and children with ADHD on average perform worse on ToM tasks than TD children, not all children in the two clinical groups show these ToM problems.

Our results should be interpreted in light of the following limitations. Our groups were matched on chronological age, but differed on estimated IQ-scores. Also, the TD group consisted of a higher percentage of girls. Because both IQ and gender are inherently confounded with ASD and ADHD (Dennis et al., 2009), we did not include these factors in our analyses. We checked post-hoc if observed differences between ASD, ADHD and TD remained, by selecting part of our TD-group (n=27) to match the IQs of both other groups. Indeed, the ASD group still was significantly impaired on FB tasks compared to the TD group ($p < .01$, $\eta_p^2 = .12$). Likewise, the ADHD group still performed worse than the TD group, and although this result did not reach significance, a medium effect size was found ($p = 0.06$, $\eta_p^2 = .08$). Similarly, we checked post-hoc if observed differences between the groups remained by only selecting the boys. Both the ASD ($p < .01$, $\eta_p^2 = .15$) and the ADHD group ($p < .05$, $\eta_p^2 = .11$) performed worse than the TD group on the FB tasks.

A second limitation is that our low-verbal ToM task was not fully comparable with the verbal ToM task. The low-verbal task contained four second-order items, while the verbal task contained seven second-order items. Furthermore, the low-verbal task took longer per item (90 seconds on average) than the verbal task (65 seconds). Additionally, during the verbal but not the low verbal task probe questions were posed by the experimenter, which may help children to keep the relevant information active and to verbalize their knowledge about false beliefs. Both TD and ADHD children scored substantially lower on the low-verbal task (Figure 1), indicating that this task was more difficult for them than the verbal task. Hence, the low-verbal task may place a higher burden on working memory. Unlike the other groups, children with ASD did not show such a large difference in performance between the two ToM tasks. It is possible that children with ASD do not rely as much on verbal information as do children with ADHD and TD children. Rather, they may make more use of spatial working memory during the low-verbal tasks (seeing where the object is), while children with ADHD rely more on verbal working memory (being told where the object is). This explanation is in line with our finding that the verbal working memory task mediates between ADHD and ToM, but not between ASD and ToM. It is also consistent with a broader literature showing that children with ADHD show stronger impairments on spatial than verbal working memory, while children with ASD are often spared or even have superior visuospatial abilities.

We conclude that children with ADHD and children with ASD show deficits in ToM performance. However, the mechanisms underlying ToM impairments seem different in children with ADHD than in children with ASD: working memory and lexical-verbal ability mediate performance on the ToM tasks in children with ADHD. In contrast, the scores on ToM tasks in ASD seem to reflect genuine ToM problems – at least not explained by working memory, inhibition, or lexical-semantic ability. This suggests that social dysfunctioning of children with ADHD may have a different origin than the social problems of children with ASD.