Research in Developmental Disabilities 34 (2013) 817–830

Contents lists available at SciVerse ScienceDirect

Research in Developmental Disabilities

Cognitive variability in adults with ADHD and AS: Disentangling the roles of executive functions and social cognition

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ARTICLE INFO

Article history:
Received 20 September 2012
Received in revised form 8 November 2012
Accepted 8 November 2012
Available online 7 December 2012

Keywords:
Attention-deficit hyperactivity disorder
Asperger Syndrome
Social cognition
Executive functions
Theory of mind
Inter-individual variability
Cognitive heterogeneity

ABSTRACT

Attention-deficit/hyperactivity disorder (ADHD) and Asperger's Syndrome (AS) share a heterogeneous cognitive profile. Studies assessing executive functions (EF) and social cognition in both groups have found preserved and impaired performances. These inconsistent findings would be partially explained by the cognitive variability reported in these disorders. First, the present study explored the inter-individual variability in EF and social cognition in both patient groups. Second, we compared differential characteristics and commonalities in the cognitive profiles of EF and social cognition between ADHD, AS and control adults. We assessed 22 patients with ADHD, 23 adults with AS and 21 matched typically developing subjects using different measures of EF (working memory, cognitive flexibility and multitasking) and social cognition (theory of mind and decision-making). Group comparisons and *multiple case series analyses* (MCSA) were conducted. The between-group comparisons showed an EF deficit in working memory in ADHD and a theory of mind (ToM) impairment in AS. The MCSA evidenced that, compared to controls, ADHD patients had a higher inter-individual variability in EF, while individuals with AS had a more heterogeneous profile in social cognition tasks compared to both groups. Finally, the AS and ADHD groups presented higher task-related variability compared to controls and shared a common heterogeneous profile in EF. This is the first study to compare variability in EF and social cognition profiles of ADHD and AS. We propose that heterogeneity in EF performance is a link between ADHD and AS which may explain the overlap of symptomatology between both diagnoses. In addition, patients with AS seem to show a unique heterogeneous profile in ToM which may explain the low probability of finding AS symptoms in patients with ADHD.

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[1] Equal contribution to the manuscript.
[2] This work is part of the PhD dissertation [M.L. Gonzalez-Gadea] ongoing by the author at UNC, Argentina.

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http://dx.doi.org/10.1016/j.ridd.2012.11.009

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) and Asperger's Syndrome (AS) are neurodevelopmental disorders that persist into adulthood with a heterogeneous cognitive profile (Geurts et al., 2008; Happe, Ronald, & Plomin, 2006; Hill & Bird, 2006; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005; Sonuga-Barke, 2002). Although ADHD diagnosis in patients with AS are part of the exclusionary criteria for AS (American Psychiatric Association, 2000), an overlap of symptoms between both disorders has been extensively reported (Ames & White, 2011; Dickerson Mayes, Calhoun, Mayes, & Molitoris, 2012; Gillberg & Billstedt, 2000; Memari, Ziaee, Mirfazeli, & Kordi, 2012; Rommelse, Geurts, Franke, Buitelaar, & Hartman, 2011; Taurines et al., 2012).

The term executive functions (EF) refers to several higher-order cognitive functions required to goal-oriented behavior (Hill, 2004; Sonuga-Barke, Sergeant, Nigg, & Willcutt, 2008). From a neurocognitive perspective, ADHD and AS share a common executive dysfunction associated with deficits in fronto-striatal circuits (Castellanos & Proal, 2012; Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Cortese et al., 2012; Rommelse et al., 2011). However, studies exploring EF in each group separately have found inconsistent results. Although many reports suggest that ADHD is strongly associated with inhibitory problems, working memory, and planning difficulties (Alloway, 2011; Balint, Czobor, Meszaros, Simon, & Bitter, 2008; Desjardins, Scherzer, Braun, Godbout, & Poissant, 2010; Kofman, Larson, & Mostofsky, 2008; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Nigg, 2005) other studies failed to find deficits across these domains (Nigg, Blaskey, Huang-Pollock, & Rappley, 2002; Sonuga-Barke, 2002). Regarding patients with AS, recent reviews have also shown inconsistent findings on EF measures. Even though planning and cognitive flexibility have been the most robustly reported deficits, results have also been mixed, as some studies did not show any differences (Hill & Bird, 2006; Kaland, Smith, & Mortensen, 2008; Liss et al., 2001; Rajendran, Mitchell, & Rickards, 2005). In addition, recent studies have found that when patients are faced with more ecological tasks designed to evaluate EF (e.g., the Hotel task for multitasking assessment), adults with ADHD (Torralva, Gleichgerrcht, Lischinsky, Roca, & Manes, 2012) and patients with AS (Hill & Bird, 2006) who do not show impairments in traditional tests, do present deficits in this area.

Most studies with children have directly compared EF in ADHD and patients with AS, which indicate that both groups might have a different EF profile (Corbett et al., 2009; Ehlers et al., 1997; Goldberg et al., 2005; Semrud-Clikeman, Walkowiak, Wilkinson, & Butcher, 2010; Sergeant, Geurts, & Oosterlaan, 2002). Happe, Booth, Charlton, and Hughes (2006), reported that EF deficits in children with autism spectrum disorders (ASD), most of whom had an AS diagnosis, were less severe and more prone to improvement over time than in children with ADHD. However, the developmental progression of these neurocognitive abilities in adults remains unknown.

Another important area of study within ADHD and AS is social cognition. This construct refers to information processing related to inter-subjectivity and interactions between co-specifics, including theory of mind (ToM), decision-making, empathy, emotional processing, among others. Although deficits in social cognition were long believed to constitute a core deficit in individuals with AS (Happe, Booth, Charlton, & Hughes, 2006; Happe, Ronald, & et al., 2006), recent studies have also found impairments in ADHD patients (Ibanez et al., 2011; Uekermann et al., 2010). Theory of mind (ToM) is one of the most robustly proven social cognition deficits in patients with AS (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Zalla, Sav, Stopin, Ahade, & Leboyer, 2009). However, the selection of a sensitive task to evaluate this function remains controversial. Several studies have reported ToM deficits in AS adults employing the Faux Pas test (FPT; Torralva, Gleichgerrcht, Roca, & et al., 2012; Zalla, Sav, Stopin, et al., 2009), but normal performance using the Reading the Mind in the Eyes test (RMET; Baron-Cohen et al., 1997, 2001; Torralva, Gleichgerrcht, Roca, & et al., 2012). Nonetheless, two studies found impaired performance using the latter (Ponnet, Roeyers, Buysse, De Clercq, & Van der Heyden, 2004; Spek, Scholte, & Van Berckelaer-Onnes, 2010). Regarding individuals with ADHD, prior research has focused mostly on children (Uekermann et al., 2010), finding that ToM deficits are not strongly present in these patients (Geurts, Broeders, & Nieuwland, 2010). To our knowledge, ToM abilities have not been compared between adults with ADHD and patients with a specific AS diagnosis. Nevertheless, there are some comparative studies between patients with ADHD and ASD where no differences between groups were detected (Buitelaar, Swaab, van der Wees, Wildschut, & van der Gaag, 1996; Nyden et al., 2010), and one study showed a selective ToM impairment in the ASD group (Dyck, Ferguson, & Shochet, 2001).

In addition, decision-making is a social cognition domain that is starting to be explored across the ADHD and AS literature. In patients with AS, no deficits in this process have been found (Johnson, Yechiam, Murphy, Queller, & Stout, 2006; Solomon, Smith, Frank, Ly, & Carter, 2011; Torralva, Gleichgerrcht, Roca, & et al., 2012), whereas in ADHD individuals, both impairment (Mantyla, Still, Gullberg, & Del Missier, 2012; Matthies, Philipsen, & Svaldi, 2012) and intact behavioral performance have been reported (Ibanez et al., 2012). Nonetheless, no previous decision-making studies comparing both disorders have been published.

In sum, both EF and social cognition domains have been considered preserved and impaired in individuals with ADHD and AS. One of the facts that could be associated with this inconsistent findings is the cognitive variability reported in both ADHD (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Nigg, 2005; Sonuga-Barke, 2005) and AS (Baez et al., 2012; Happe, Ronald, & et al., 2006; Hill & Bird, 2006; Towgood, Meuwese, Gilbert, Turner, & Burgess, 2009). Braver (2012) states that cognitive variability can be differentiated between intra-individual (variability in performance in the same individual on a single test or on multiple tests) and inter-individual or trait-related variation (variability among individuals in the same

Table 1
Demographic data for each group.

	ADHD (n = 22)	AS (n = 23)	Control (n = 21)	p
Age (years)	35.27	33.00	38.29	.37
Gender (F:M)	8:14	8:15	10:11	.31
Education (years)	15.14	14.91	15.67	.67
WAT*	37.00	37.43	37.14	.91

* Word accentuation test (premorbid intellectual level).

group). Several reports have found high intra-individual variability in measures of reaction times in subjects with ADHD (Castellanos et al., 2005; Di Martino et al., 2008; Klein, Wendling, Huettner, Ruder, & Peper, 2006) and recently, also in children with high functioning autism (Geurts et al., 2008). Only a few studies with AS patients have reported a high inter-individual variation between these individuals (Baez et al., 2012; Hill & Bird, 2006; Towgood et al., 2009).

Most of the ADHD and AS studies have been focused on group comparison analyses (e.g., analyses of variance) which are problematic for individuals with high variability in performance because of the *averaging artifact* (Shallice & Evans, 1978). In other words, these analyses cannot describe the domains in which a single member shows abnormal performance. Therefore, a significant difference between groups is not necessarily an index of individual's impairment on this measure (Hill & Bird, 2006; Nigg et al., 2005; Willcutt, Sonuga-Barke, Nigg, & Sergeant, 2008). A recently developed methodology called multiple case series analysis (MCSA; Hill & Bird, 2006; Towgood et al., 2009) has been used to overcome these obstacles. By exploring the ranges of performance in an extended battery of cognitive tests, this new approach detects the domains in which a given individual displays sub-normal or supra-normal performance.

The current study aimed to explore inter-individual variability in EF and social cognition in ADHD, AS, and controls employing MCSA. We expected to find higher variability in performance across participants from both patient groups compared to controls. Furthermore, ADHD patients' performance was expected to be more variable in EF, while AS individuals would exhibit a heterogeneous profile in social cognition tasks.

In addition, by using the traditional group comparison analysis, we compared differential characteristics and commonalities in the cognitive profiles of EF and social cognition between ADHD, AS, and controls. We expected to find impairments in working memory in the ADHD group and deficits in cognitive flexibility in patients with AS. Moreover, we hypothesized that both groups would show difficulties in solving the more ecological task of EF (Hotel multitasking). Regarding social cognition domains, we expected that the AS group would be impaired in performance on ToM tests and patients with ADHD would have difficulties performing decision-making tasks. Finally, we also hypothesized that MCSA would reveal patterns of cognitive profile varying within and/or between individuals, while variation would not be established in group comparison analyses.

2. Methods and materials

2.1. Participants

Sixty-six participants were recruited. Twenty-two ADHD patients (M = 35.2 years, SD = 12.7), 23 adults diagnosed with AS (M = 33.0 years, SD = 9.8), and 21 typically developing subjects (M = 38.2 years, SD = 14.4) were assessed (see Table 1). Patients in the ADHD and AS groups were selected from a large outpatient population of the Institute of Cognitive Neurology (INECO) using the following inclusion criteria: (1) subjects older than 18 years old; (2) diagnosed with ADHD or AS according to the diagnostic and statistical manual of mental disorders DSM-IV (American Psychiatric Association, 2000). Patients were evaluated during admission interviews to the specialized clinic of ADHD and AS at INECO, where they underwent a detailed examination that included neuropsychatric assessment, neurological examination, and neuropsychological evaluation. Questionnaires were incorporated in the regular neuropsychiatric examination. Relatives or significant others were usually integrated in the assessment interviews, during which they completed the informant-based version of questionnaires. The DSM-IV based diagnoses for ADHD and AS were made by experts (A.L and F.M for ADHD and A.R for AS) following the criteria described in our previous reports (Torralva et al., 2011; Torralva, Gleichgerrcht, Lischinsky, & et al., 2012; Torralva, Gleichgerrcht, Roca, & et al., 2012). In addition, for AS diagnosis we employed the adult Asperger assessment (AAA; Baron-Cohen, Wheelwright, Robinson, & Woodbury-Smith, 2005), including assessments of the Autism Spectrum Quotient (AQ; M = 34.27, SD = 8.74) and the Empathy Quotient (EQ; M = 19.72, SD = 15.11). Patients were examined to rule out other possible comorbid psychiatric and neurological disorders or history of drug or alcohol abuse (exclusion criteria). During the assessment, patients with ADHD were taking methylphenidate (54.5%), atomoxetine (9.1%), and benzodiazepines (18.8%), either alone or combined. The rest of the patients with ADHD (36.3%), all individuals with AS, and controls were not taking any medication.

Typically developing controls were matched with the patients for sex, age, handedness, years of education, and intellectual level, and were recruited from a large pool of volunteers. Their intellectual levels were evaluated by the Word Accentuation Test (WAT-BA; Burin, Jorge, Arizaga, & Paulsen, 2000). All participants provided written informed consent in agreement with the Helsinki Declaration. This work was approved by the ethics committee of INECO.

2.2. Instruments

2.2.1. EF

2.2.1.1. Working memory. *2.2.1.1.1. Backwards Digit Span.* For this task, subjects were asked to repeat a progressively lengthening string of digits in the reverse order (Weschler, 2007). The score was the longest span of digits the participant accurately recalled (maximum 9 points).

2.2.1.1.2. Letters and numbers (Weschler, 2007). Participants are presented with an increasing number of letters and digits and are asked to repeat them in a way such that numbers are ordered in an ascending fashion and letters arranged alphabetically (maximum 21 points).

2.2.1.2. Cognitive flexibility.

2.2.1.2.1. Wisconsin Card Sorting Test (WCST). We used the card sorting modified version (Nelson, 1976) in which ambiguity is eliminated by removing those cards that share more than one attribute with the stimulus cards. Score was the number of categories completed (range: 0–6).

2.2.1.2.2. Trail Making Test part B (TMT-B). Participants were asked to join 25 randomly arranged numbers and letters in an alternating fashion. Score was the number of seconds required to complete the task (Partington & Leiter, 1949).

2.2.1.3. Multitasking. We included the Hotel task (Torralva, Roca, Gleichgerrcht, Bekinschtein, & Manes, 2009), a multitasking test, which comprises five activities that would plausibly need to be completed in the course of running a hotel. The scores included: (i) number of main tasks attempted (out of 5); (ii) number of tasks attempted correctly (out of 5); (iii) time allocation—the optimal allocation was 3 min per task- and deviations (in seconds) from this timeframe were calculated and totaled.

2.2.2. Social cognition measures

2.2.2.1. ToM.

2.2.2.1.1. RMET. This test (Baron-Cohen et al., 1997) assesses the emotional inference of ToM. This is a computerized and validated test in which 17 images, showing the face from midway along the nose to just above the eyebrows, are presented. The patient is forced to choose the option that best describes what the person in the picture is thinking or feeling. The score was total number correct (maximum 17 points).

2.2.2.1.2. FPT. This task assesses the emotional and cognitive inference aspects of the ToM. In this task, participants read stories that may contain a social faux pas (Stone, Baron-Cohen, & Knight, 1998). After each story is read, the subject is asked whether someone said something awkward (in order to identify stories containing a faux pas). If a faux pas is detected, clarifying questions are asked. Each story is presented to the participant to decrease working memory load. Scoring was computed by adding the number of correctly detected faux pas and the number of correctly detected non-faux pas scenarios (maximum 20 points).

2.2.2.2. Decision-making.

2.2.2.2.1. Iowa Gambling Task (IGT). The computerized version of the IGT (Bechara, Damasio, Damasio, & Anderson, 1994) involves continuous card selections from four separate decks (A, B, C, and D) and is completed after 100 selections. Each card choice is awarded a certain number of points, but some choices yield penalties. Card choices from Decks A and B (''high risk'') generate large wins ($100) but also heavy losses that may lead to an overall debt. Decks C and D (''low risk'') generate smaller wins ($50 per choice) but also smaller penalties. Persistent selections from these decks yield a profit. The dependent variable of this task is the net score, which is calculated by subtracting the number of choices from the high-risk decks (A + B) from the choices from the low-risk decks (C + D). To quantify the change in decision-making across the course of the task, we divided this task into five blocks, each with 20 consecutive card choices. The net score was the sum of the five blocks.

2.3. Data analysis

Demographic and neuropsychological data were compared between groups using ANOVA and Tukey's HSD posthoc test (when appropriate). When analyzing categorical variables (e.g., sex), the chi square test was applied. The α value for all statistical tests was set at 0.05. Eta squared (η^2) effect size measures were computed for significant effects.

To assess inter-individual differences, we conducted a MCSA and compared each participant with the control group on every performance measure. We followed the method of Towgood et al. (2009) and used a threshold of 2 standard deviations (SD) from the mean of the control group to define the normal range. First, we identified control subjects who displayed abnormal performance in each sub-measure, according to the 2SD criteria, and removed them. Then, we recomputed control means and SD after excluding these subjects and identified ADHD, AS, and control participants who were below (−2SD) or above (+2SD) this mean. We carried out frequency analyses in order to record the instances in which the performance of each subject was sub-normal or supra-normal. We then used non-parametric tests (Mann–Whitney tests [U]) to compare the number of measures with impaired and supra-normal performance.

Table 2
Means, standard deviation (SD), and group differences in EF and social cognition measures.

		ADHD ($n = 22$)		AS ($n = 23$)		Control ($n = 21$)		ADHD vs. Control	AS vs. Control	ADHD vs. AS
		Mean	SD	Mean	SD	Mean	SD	p	p	p
Executive functions	Backwards Digit Span	4.18	.91	5.61	1.31	5.43	1.47	.00	.88	.00
	Letters & Numbers	8.91	2.33	11.09	2.97	11.33	2.54	.02	.95	.01
	TMT-B	78.23	35.41	69.13	27.9	61.4	22.83	.16	.66	.55
	WCST	5.86	.35	5.17	1.67	5.8	.52	.97	.13	.08
	Hotel – number of tasks attempted	4.55	.67	4.43	.99	4.81	.4	.47	.22	.87
	– Tasks correctly attempted	4.55	.67	4.43	.99	4.76	.44	.60	.31	.87
	– Time allocation	437.24	261.19	458.48	272.52	387.7	134.77	.77	.58	.95
Social cognition	RMET	14.14	1.08	13.7	2.29	13.95	1.28	.92	.86	.64
	FPT	18.71	2.39	16.17	2.77	19.12	1.17	.85	.00	.00
	IGT – net score	4.51	21.13	16.5	24.3	12.22	21.03	.53	.81	.18
	– Block 1	−0.14	3.77	−1.74	5.06	−1.00	6.59	.86	.89	.56
	– Block 2	−0.48	5.40	4.22	7.37	0.22	5.44	.93	.11	.04
	– Block 3	0.76	7.31	3.48	7.49	3.33	5.31	.47	.99	.39
	– Block 4	2.24	7.85	3.87	8.73	5.11	8.07	.52	.88	.79
	– Block 5	1.76	7.96	7.39	10.40	4.44	9.09	.64	.57	.11

3. Results

3.1. Demographic data

No differences in age, $F(2, 63) = 0.99$, $p = .37$, sex, $X^2(2) = 2.30$, $p = .31$, years of formal education, $F(2, 63) = 0.39$, $p = .67$, or intellectual level $F(2, 63) = 0.08$, $p = .91$, were observed between groups (see Table 1).

3.2. Group differences analysis

Table 2 summarizes the group comparisons. A one-way analysis of variance was performed on each measure of the tests.

3.2.1. EF measures

Significant differences between groups were observed on both tasks of working memory (see Fig. 1a and b). First on the Backwards Digit Span test, $F(2, 63) = 8.60$, $p < .01$, $\eta^2 = .21$, where a posthoc analysis, Tukey HSD, $MS = 1.55$, $df = 63.00$, showed that the ADHD group obtained lower scores than patients with AS ($p < .01$) and controls ($p < .01$). Secondly, significant differences on the Letters & Numbers task were observed, $F(2, 62) = 5.61$, $p < .01$, $\eta^2 = .15$. Again, the posthoc comparisons, Tukey HSD, $MS = 6.90$, $df = 62.00$, revealed that ADHD patients obtained an inferior performance than AS ($p < .01$) and control participants ($p < .01$). No group differences were found on cognitive flexibility, neither in TMT-B, $F(2, 62) = 1.73$, $p = .18$, nor in WCST, $F(2, 62) = 2.91$, $p = .06$. Similarly, no differences were observed on all the multitasking measures (number of tasks attempted, $F(2, 63) = 1.47$, $p = .23$; tasks correctly attempted, $F(2, 63) = 1.08$, $p = .34$, and time allocation, $F(2, 61) = .50$, $p = .60$).

3.2.2. Social cognition tasks

Group differences were found on the FPT, $F(2, 58) = 10.21$, $p < .01$ $\eta^2 = .26$. A posthoc analysis, Tukey HSD, $MS = 5.26$, $df = 58.00$, showed that patients with AS obtained lower scores on this test compared to ADHD participants ($p < .01$) and controls ($p < .01$). However, no significant differences were observed on another ToM measure (RMET), $F(2, 63) = .40$, $p = .66$.

Regarding decision-making, the IGT net score did not reveal between-group differences $F(2, 59) = 1.60$, $p = .20$. Furthermore, we did not observe an interaction between blocks and groups (see Fig. 1b). We found significant group differences only in block 2, $F(2, 59) = 3.63$, $p < .01$, $\eta^2 = .10$. Posthoc comparisons, Tukey HSD, $MS = 38.58$, $df = 59.00$ revealed that AS individuals performed better than ADHD patients ($p < .05$) in this block.

In summary, the ADHD group showed EF deficits in working memory (Digit Span and Letters & Numbers subtests), while the AS group exhibited difficulties in social cognition, specifically in ToM (FPT, see Fig. 1c).

3.3. Multiple case series analysis (MCSA)

We identified those individuals who were outside the normal distribution of the control group on every measure (see Tables 3a–3c) to examine cognitive variability among the AS and ADHD groups. These participants, considered outliers, were

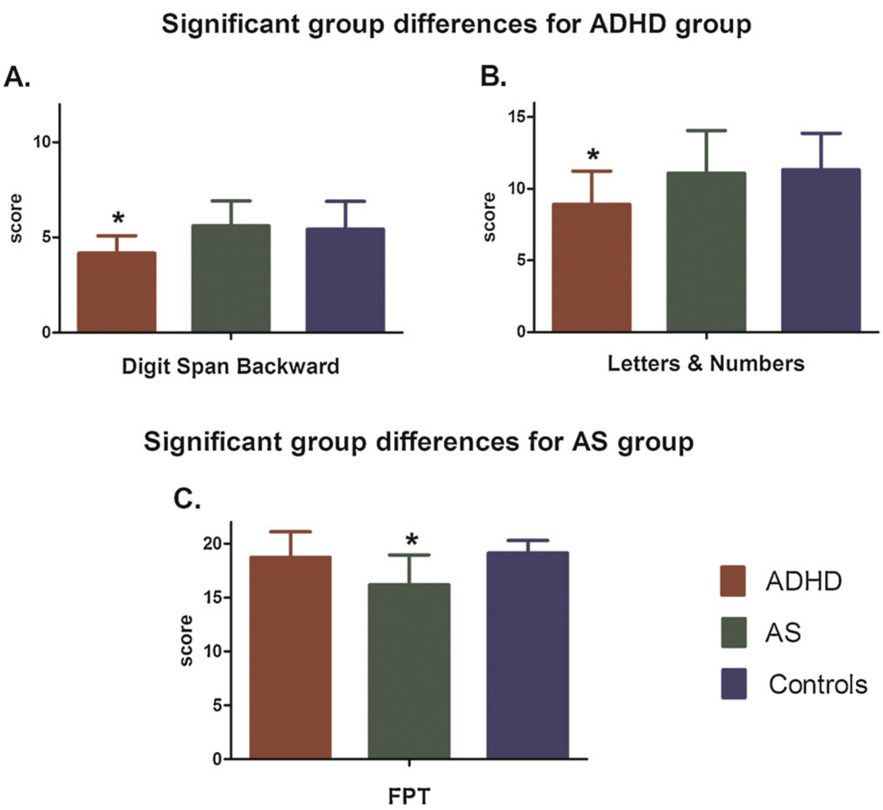

Fig. 1. Significant group differences. Significant group differences between ADHD, AS, and control groups in Backwards Digit Span (A), Letters & Numbers task (B) and the Faux Pass task (C). Columns represent mean scores from each measure. Vertical bars represent the standard error of the mean. FPT: Faux Pass task.

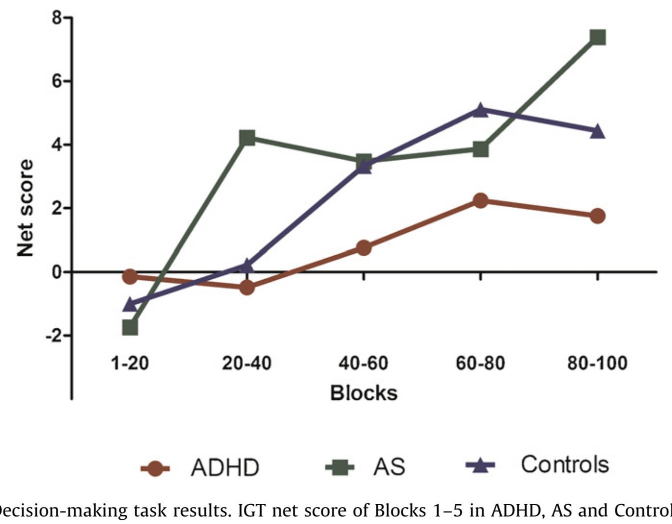

Fig. 2. Decision-making task results. IGT net score of Blocks 1–5 in ADHD, AS and Control groups.

detected following the method developed by Towgood et al. (2009). Thus, the control group's threshold of ±2SD identified supra-normal performers (>2SD above the control group's mean) and sub-normal performers (<2SD below the control group's mean).

3.3.1. Task-related variability

We calculated the percentage of sub- and supra-normal performers and the percentage of outliers (sub-normal + supra-normal performers) for each group and every measure. For tasks involving more than one variable we only included the main measure (time allocation for the Hotel task and net score from the IGT).

In the control group, the maximum percentage of outliers was 19.05% (see Table 3c). Regarding the ADHD group, three measures (from eight) exceeded this maximum percentage (see Table 3a). Working memory exhibited the highest proportion of individuals with atypical performance (Letters & Numbers with 45.4%). In addition, there was a high percentage of outliers in multitasking (Hotel time with 40.9%) and cognitive flexibility (TMT-B with 36.34%).

Concerning the AS group, six measures (from eight) exceeded the maximum proportion of participants with atypical performance from the control group (see Table 3b). AS patients exhibited the highest proportion of outliers in ToM tasks (FPT with 43.5% and RMET with 34.8%) followed by multitasking (Hotel task time with 26.1%), both measures of cognitive flexibility (TMT-B with 26.1% and WCST with 21.7%), and working memory (Letters & Numbers with 26.1%).

These descriptive data suggest that patients with ADHD and AS showed a high task-related variability in some EF tasks, such as multitasking and cognitive flexibility (except for WCST in the ADHD group) that was concealed in the groups comparisons' analyses. In addition, both groups present a high task-related variability in working memory, but in the Letters & Numbers task only. Regarding social cognition, the AS group exhibited a high task-related variability in both measures of ToM (FPT and RMET). Finally, low task-related variability in decision-making was observed in the groups.

3.3.2. Inter-individual variability

We recorded the instances in which performance was 2SD below or above the control mean for each participant. A non-parametric test was applied to compare the number of measures for sub-normal and supra-normal performance (see Table 4). As expected, significant differences were observed for the total number of measures with impaired performance in both ADHD, $U = 113.00$, $p < .01$, and patients with AS, $U = 148.00$, $p < .05$, compared to controls. However, no significant differences were observed between the AS and ADHD groups, $U = 244.00$, $p = .12$. Also, no differences were observed in the total number of measures with supra-normal performance between ADHD patients and controls, $U = 225.00$, $p = .83$, AS and controls, $U = 185.00$, $p = .10$, and ADHD and AS groups, $U = 198.00$, $p = .12$.

To explore the cognitive heterogeneity in each cognitive domain, we recorded the number of impaired and supra-normal performances for sub-measures that involved EF (Backwards Digit Span, Letters & Numbers, TMT-B, WCST, and Hotel task) and social cognition (RMET, FPT, and IGT net score) for each participant. Again, a non-parametric test was utilized to compare the number of measures with impaired and supra-normal performance in each domain (see Table 4). First, ADHD

Table 3a
Individual profiles of performance for each patient with ADHD*.

Participant	Backwards digit span	Letters & Numbers	TMT-B	WCST	Hotel time	RMET	FPT	IGT net score	% outliers
1									37.50
2									37.50
3									12.50
4									25.00
5									25.00
6									0
7									25.00
8									25.00
9									0
10									37.50
11									25.00
12									12.50
13									12.50
14									37.50
15							2		25.00
16									0
17									25.00
18									12.50
19									25.00
20									0
21									37.50
22									12.50
% < 2 SDs	0	40.90	36.36	13.64	27.27	0	13.64	9.09	
% > 2 SDs	0	4.54	0	0	13.64	0	4.55	0	
% outliers	0	45.45	36.36	13.64	40.91	0	18.18	9.09	

*Grey shaded cells show participants whose performance was 2 SDs below the control mean (sub-normal performers). Black shaded cells show participants whose performance was 2 SDs above the control mean (supra-normal performers).

Table 3b
Individual profiles of performance for each patient with AS*.

Participant	Backwards digit span	Letters & Numbers	TMT-B	WCST	Hotel time	RMET	FPT	IGT net score	% outliers
1									62.50
2									25.00
3									25.00
4									0
5									12.50
6									25.00
7									12.50
8									25.00
9									12.50
10									25.00
11									37.50
12									0
13									0
14									50.00
15									62.50
16									12.50
17									0
18									37.50
19									12.50
20									50.00
21									37.50
22									12.50
23									25.00
% < 2 SDs	0	17.39	26.09	21.74	17.39	21.74	43.48	0	
% > 2 SDs	4.35	8.70	0	0	8.70	13.04	0	13.04	
% outliers	4.35	26.09	26.09	21.74	26.09	34.78	43.48	13.04	

*Grey shaded cells show participants whose performance was 2 SDs below the control mean (sub-normal performers). Black shaded cells show participants whose performance was 2 SDs above the control mean (supra-normal performers).

participants exhibited a higher number of sub-measures with impaired performance in EF when compared to controls, $U = 130.00$, $p < .01$, but not compared to the AS group, $U = 193.00$, $p = .15$. The ADHD group did not differ to controls and AS group in the number of sub-measures with supra-normal performance on EF nor on the number of sub-measures with sub- or supra-normal performance on social cognition.

Secondly, participants with AS differed from controls, $U = 145.50$, $p < .01$, and individuals with ADHD, $U = 179.00$, $p < .05$, in the number of sub-measures with impaired performance in social cognition tasks. No differences were observed between the AS group and controls or between the AS and ADHD groups on the number of social cognition measures with supra-normal performance and the EF measures with sub-normal and supra-normal performances.

In summary, adults with ADHD and AS exhibited a higher total number of measures with sub-normal performance than controls. Specifically, ADHD individuals were more variable in EF than controls but not than patients with AS. The AS group exhibited more heterogeneous profiles in social cognition tasks compared to controls and ADHD adults (see Fig. 3).

4. Discussion

In the present study we compared profiles of EF and social cognition between adults with ADHD and AS (relative to typically developing individuals), and explored the underlying variability in performance across these cognitive domains. Individuals with ADHD demonstrated an EF deficit in working memory, while patients with AS showed social cognition difficulties in ToM. A detailed analysis of individual cases revealed an increased task-related variability among both patient groups compared to controls. Furthermore, ADHD and AS individuals share a common heterogeneous profile in EF, while patients with AS seem to show a unique heterogeneous profile in ToM. This is the first study that compares variability in cognitive profile between both disorders. We propose that heterogeneity in EF is a link between ADHD and AS while ToM heterogeneity is a distinctive feature associated with adults diagnosed with AS.

4.1. EF profiles of ADHD and AS adults

Deficits in EF are the most robustly found common features between ADHD and AS (Rommelse et al., 2011). However, previous reports that studied each disorder separately showed inconsistent findings (see reviews of Happe, Ronald, & et al.,

Table 3c
Individual profiles of performance for each control individual*.

Participant	Backwards digit span	Letters & Numbers	TMT-B	WCST	Hotel time	RMET	FPT	IGT net score	% outliers
1									0
2									0
3									0
4									0
5									12.50
6									0
7									12.50
8									25.00
9									0
10									12.50
11									0
12									12.50
13									0
14									0
15									12.50
16									25.00
17									37.50
18									12.50
19									0
20									25.00
21									12.50
% < 2 SDs	0	14.29	19.05	14.29	0	4,76	0	0	
% > 2 SDs	9.52	4.76	0	0	4.76	0	0	4.76	
% outliers	9.52	19.05	19.05	14.29	4.76	4,76	0	4.76	

*Grey shaded cells show participants whose performance was 2 SDs below the control mean (sub-normal performers). Black shaded cells show participants whose performance was 2 SDs above the control mean (supra-normal performers).

Table 4
Extreme ranges of performance in FE, social cognition, and total measures from each group.

	ADHD		AS		Control		ADHD/Ctrls	AS/Ctrls	ADHD/AS
	Mean	SD	Mean	SD	Mean	SD	*p*	*p*	*p*
EF measures sub-normal	1.18	0.95	0.83	1.11	0.48	0.87	.00	.26	.15
EF measures supra-normal	0.18	0.39	0.22	0.42	0.19	0.41	.79	.58	.76
Social cognition measures sub-normal	0.18	0.39	0.65	0.83	0.05	0.21	.17	.00	.03
Social cognition measures supra-normal	0.09	0.29	0.26	0.44	0.05	0.21	.58	.05	.14
Total measures sub-normal	1.41	1.05	1.48	1.53	0.48	0.87	.00	.01	.83
Total measures supra-normal	0.23	0.42	0.48	0.59	0.24	0.53	.83	.10	.12

Shown is the number of EF measures (Backwards Digit Span, Letters & Numbers, TMT-B, WCST, and Hotel time), and social cognition measures (RMET, FPT, and IGT net score) where performance were either 2SDs below the mean of the controls (sub-normal), more than 2SDs above it (supra-normal), or both values summed for each measures sub- and supra-.

2006; Hill, 2004; Rommelse et al., 2011; Sergeant et al., 2002). To our knowledge, this is the first comparative study investigating EF in adults with ADHD and AS. We explored the profiles of EF in both disorders employing group comparison analyses and MCSA (Towgood et al., 2009).

As expected, ADHD patients under-performed compared to controls and the AS group on working memory. This finding is consistent with previous studies that found working memory difficulties to be one of the most robust deficits in ADHD patients (Barkley, 1997; Martinussen et al., 2005).

On the other hand, we failed to find impairments in cognitive flexibility in patients with AS that could be explained by the selected measures to evaluate this function. Thus, a recent review suggests that the modified version of WCST and the TMT-B are not sensitive instruments to evaluate cognitive flexibility deficits in patients with ASD (Geurts, Corbett, & Solomon, 2009). In addition, contrary to our hypotheses, we found intact performance in the ecological measure of EF in both the ADHD and AS groups (Hotel multitasking). Some previous studies also found no deficit in multitasking tasks in individuals with ADHD (Gawrilow, Merkt, Goossens-Merkt, Bodenburg, & Wendt, 2011; Siklos & Kerns, 2004). Although this function

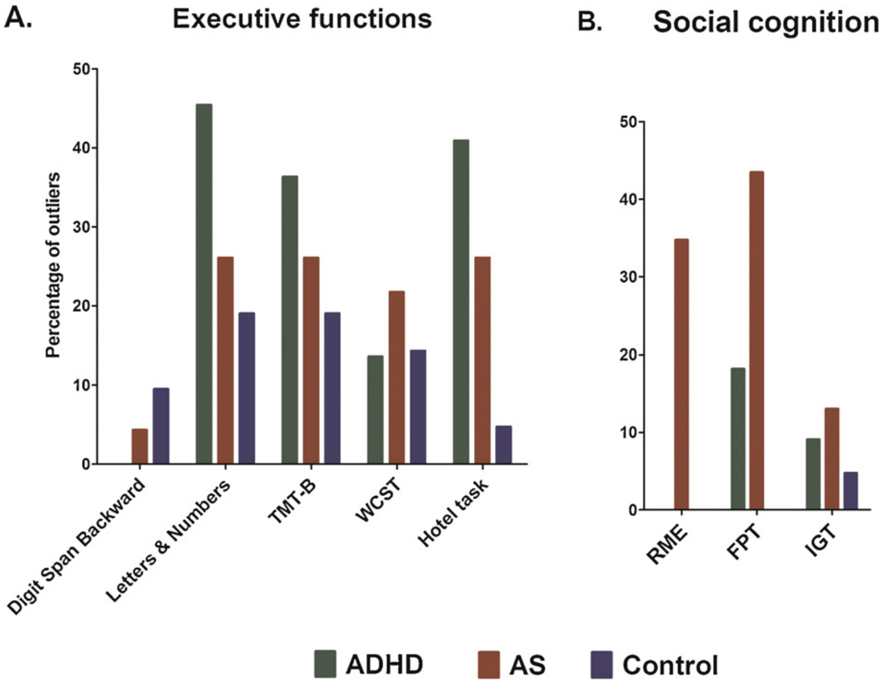

Fig. 3. Main results summary of individual comparisons. Percentage of individuals with abnormal performance on each measure from the neuropsychological assessment. Columns represent the percentage of individuals with abnormal performance (both impaired and supra-normal performance, see Tables 3a and 3b for a detailed description). TMT-B: Trail Making Test part B. WSCT: Wisconsin Card Sorting Test. RMET: Reading the Mind in the Eyes test. FPT: Faux Pass task. IGT: Iowa Gambling Task.

has been less studied in adults with AS, the only published report observed a deficit and high performance variability in this domain (Hill & Bird, 2006).

One of the facts that would explain the lack of significant differences between groups on these measures is the high task-related variability found in both groups. For instance, cognitive flexibility (WCST and TMT-B) exhibit a high percentage of outliers in the AS group. Concerning performance on multitasking, both ADHD and AS groups obtained a high variability compared to controls. Overall, a detailed MCSA revealed that both groups show a high task-related variability compared to controls in almost all EF. These findings suggest that the lack of significant differences between groups in EF was not necessarily an index of intact performance. A further analysis also revealed that individuals with ADHD differed significantly from controls (and not from AS group) in the total number of EF measures with sub-normal performance.

Thus, rather than group impairments, heterogeneity in EF is a common feature that links ADHD with AS. In the same vein, a recent review has proposed the assessment of EF as a useful tool to study comorbidity profiles between ADHD and ASD (Gargaro, Rinehart, Bradshaw, Tonge, & Sheppard, 2011). Moreover, several authors have claimed that heterogeneity in performance during cognitive tasks in ADHD (Nigg, 2005; Nigg et al., 2005; Sonuga-Barke et al., 2008) and AS groups (Happe, Ronald, & et al., 2006) is rarely addressed in empirical reports. Previous studies showed that abnormal EF performance has been demonstrated only in a range of patients with ADHD (Nigg, 2005; Sonuga-Barke et al., 2008; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005), and in a portion of children as well as adults with AS (Hill & Bird, 2006; Towgood et al., 2009). This is the first report that suggests heterogeneity in EF as a common feature of ADHD and AS.

4.2. Social cognition profiles of ADHD and AS adults

Traditionally, social cognition has been proposed as a core deficit among patients with AS (Happe, Ronald, & et al., 2006; Rajendran & Mitchell, 2007). However, recent studies have also suggested social cognition difficulties in ADHD (Nijmeijer et al., 2008; Soliva et al., 2009; Uekermann et al., 2010). No previous reports have compared social cognition between adults with ADHD and AS. Our results showed a group impairment in ToM domains and high task-related variability in these tasks in the AS group. We suggest that heterogeneity and deficits in ToM is a unique feature of patients with AS relative to adults with ADHD.

As we hypothesized, the AS group differs significantly from both ADHD and controls in ToM. However, these differences were only exhibited in the FPT and not in the RMET. Previous studies also reported no differences between patients with AS and controls in the RMET (Ponnet et al., 2004; Spek et al., 2010; Torralva, Gleichgerrcht, Roca, & et al., 2012) while deficient performance in the FPT has been consistently demonstrated (Spek et al., 2010; Torralva, Gleichgerrcht, Roca, & et al., 2012;

Zalla, Sav, & Leboyer, 2009). The discrepancies in the performances of the AS group on the ToM tests were further explored by the MCSA.

Individuals with AS exhibited both sub- and supra-normal performance on the RMET, while a high number of patients obtained sub-normal performance in the FPT. We suggest that these tasks' features may explain these discrepancies. The RMET could be solved by using compensatory strategies to match the depicted eyes and emotions correctly. Thus, differences in the employment of these strategies may explain the performance variability in the RMET. Instead, the FPT presents social scenarios resembling daily life situations. Tasks involving real-life social scenarios are more sensitive to detect ToM deficits of individuals with autism and AS (Baez et al., 2012).

As previously reported (although not consistently), no deficits in ToM were found in individuals with ADHD (Dyck et al., 2001; Geurts et al., 2010). However, MCSA revealed a high task-related variability between these patients in the FPT (both sub- and supra-normal performance). The FPT is a complex task that demands a high load of attention and working memory (Stone et al., 1998). We suggest that fluctuations in attention or working memory difficulties may influence the heterogeneity in performance in adults that have ADHD.

Regarding decision-making, although ADHD individuals performed worse compared to patients with AS and controls across the course of the IGT (Fig. 2), significant differences were only found in the second block of the task. Contrary to our expectations, but consistent with some previous reports (Ernst et al., 2003; Ibanez et al., 2012), we observed intact ADHD performance in the IGT net score. Similarly, patients with ADHD exhibited a low task-related variability in this test. This profile may be explained by the measure chosen to evaluate decision-making. Recent authors (Masunami, Okazaki, & Maekawa, 2009) have proposed that rather than the net score value, differences in decision-making strategies focused on choice patterns associated with rewards and punishments are more sensitive measures of decision-making in patients with ADHD.

4.3. Clinical and empirical implications

An overlap of symptoms between ADHD and patients with AS is often observed during clinical assessment (Dickerson Mayes et al., 2012; Taurines et al., 2012). Indeed, some of the core features of AS, including poor social skills (Mikami, 2010), lack of awareness of others' feelings (Nijmeijer et al., 2009), and stereotypic behavior have been reported in patients with ADHD (Hartley & Sikora, 2009). Similarly, some of the core features of ADHD such as attention problems, hyperactivity, and impulsivity have been observed in individuals with AS (Dickerson Mayes et al., 2012). Studies focused on children showed that there is a higher probability of finding children with AS who meet criteria for ADHD than the inverse (finding children with ADHD who meet criteria for AS) (Dickerson Mayes et al., 2012; Nyden et al., 2010; Rommelse et al., 2011). In addition, a recent report comparing the overlap in symptomatology between children with ADHD and ASD suggested that ADHD symptoms are part of ASD but autistic symptoms are not common in ADHD (Dickerson Mayes et al., 2012). Our results suggest that a common heterogeneous profile in EF shared by adults with ADHD and AS may explain the overlap of symptomatology between both diagnoses. In the same vein, heterogeneity in social cognition domains as a characteristic feature of AS patients may explain the low probability of finding AS symptoms in patients with ADHD.

On the other hand, most of the empirical research on ADHD and AS has applied group comparison analyses, in which the implicit assumption of homogeneity between subjects concealed the high variability in performance that both groups of patients typically exhibit. Recently, various authors have proposed to abandon the search for a single cause of ADHD and AS, and study them as complex and multifactorial disorders (Happe, Ronald, & et al., 2006; Willcutt et al., 2008). In this sense, reporting individual results such as the proportion of patients exceeding the clinical cutoff of the measures, reporting the score ranges, mean, and variance of the samples would be desirable. Also combining classical group comparisons with MCSA might provide solutions to overcome these obstacles (Hill & Bird, 2006; Nigg et al., 2005; Towgood et al., 2009).

4.4. Limitations and future directions

First, and similar to previous studies, the number of participants included in each group was moderate. Therefore, subtle differences in group comparison analyses may have been missed due to a lack of statistical power. Second, the heterogeneous cognitive profile in EF found in both ADHD and AS might be extended to other domains of EF that have not yet been explored in comparative studies of adults with ADHD and AS, such as inhibition, verbal fluency, and interference control (Nigg, 2005; Nyden et al., 2010; Rommelse et al., 2011; Verte, Geurts, Roeyers, Oosterlaan, & Sergeant, 2006). Third, many social cognition domains in ADHD adults remain unknown in comparison to patients with AS. In fact, emotion recognition, empathy, and humor processing are emerging areas for comparative studies between ADHD and AS (Uekermann et al., 2010). Fourth, heterogeneity has also been interpreted as a consequence of distinct subgroups of patients with ADHD and AS (Sonuga-Barke, 2002; Towgood et al., 2009). Nigg (2005) suggested multiple pathways to ADHD and proposed the development of new sets of diagnostic criteria for each pathway. Finally, more than half of the patients with ADHD were under pharmacological treatment. These potential confounding effects of medications on cognitive heterogeneity should be addressed in future studies.

4.5. Conclusions

Cognitive variability has been extensively reported in ADHD literature (Nigg, 2005; Nigg et al., 2005; Sonuga-Barke, 2002; Sonuga-Barke et al., 2008) and recently in AS (Happe, Ronald, & et al., 2006; Hill & Bird, 2006; Towgood et al., 2009;

Baez et al., 2012). This is the first report that compares cognitive heterogeneity between both disorders and disentangled the roles of EF social cognition for each group of patients. Thus, we suggest that adults with ADHD and AS share a common heterogeneous profile in EF while AS patients also present a unique heterogeneous profile in ToM that differs from individuals with ADHD. Our results also showed group differences in discrete domains of EF and social cognition. That is, ADHD adults exhibited impaired working memory, while patients with AS showed deficits in ToM. At the individual level, both groups demonstrated a widespread range of heterogeneity in cognitive domains. Although there has been a long history of research in ADHD and AS searching for a typical profile of deficits, the current results provide evidence to support that a heterogeneous cognitive profile of performance is the feature that better describes these disorders (Happe, Ronald, & et al., 2006; Nigg, 2005; Sonuga-Barke et al., 2008).

From a clinical perspective, the commonly found overlap of patients with AS that meets criteria for ADHD may be explained by this similarity in their EF profiles. Therefore, the fact that only a low percentage of patients with a diagnosis of ADHD meets criteria for AS is consistent with the heterogeneous ToM's profile that solely characterizes patients with AS.

These findings have important implications for the treatment, identification, and assessment of both disorders. Understanding the heterogeneity in the cognitive profiles of each patient would allow for the identification of the specific profile of adults with ADHD and AS, facilitating the development of individualized treatments that each patient requires. Although implementation would be challenging, individualized rehabilitation programs may improve the cognitive and social functioning of the patients.

Conflict of interest

None to declare.

Acknowledgments

This study was partially supported by grants CONICET, INECO Foundation, and FONDECYT (1130920). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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