Psychopathology

Research Article

Psychopathology
DOI: 10.1159/000531512

Received: November 4, 2022
Accepted: May 23, 2023
Published online: August 16, 2023

Mentalizing in Adolescents and Young Adults with Attention Deficit Hyperactivity Disorder: Associations with Age and Attention Problems

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Keywords

Attention deficit hyperactivity disorder · Adolescence · Mentalizing · Theory of mind · Social cognition

Abstract

Introduction: Growing, albeit heterogenous evidence questions whether attention deficit/hyperactivity disorder (ADHD) is associated with socio-cognitive impairments, especially beyond childhood. This study focuses on mentalizing – the socio-cognitive ability to attribute and reason in terms of mental states. We aimed to characterize mentalizing performance in terms of correct scores and types of errors in adolescents and young adults with ADHD. ***Methods:*** Forty-nine adolescents and adults with ADHD and 49 healthy controls matched for age and gender completed a computerized naturalistic mentalizing task, the Movie for Assessment of Social Cognition (MASC). Repeated measures analyses of variance examined the effects of age group and ADHD diagnosis on MASC performance. Additionally, associations between mentalizing scores, the severity of attention problems, and the presence of comorbidity were explored in the ADHD group. ***Results:*** Results showed an increased prevalence of hypomentalizing errors in adolescents with ADHD. Lower mentalizing scores in adolescents with ADHD were correlated with indices of inattentiveness, impulsivity, and vigilance problems. Hypomentalizing errors in adolescents showed to be particularly associated with inattentiveness, after controlling for age and comorbidity. In contrast, adults with ADHD performed similarly to controls and their scores on the mentalizing task were not correlated to attention problems. ***Conclusion:*** These findings highlight potential developmental differences in mentalizing abilities in ADHD youths and their association with attentional impairments.

Introduction

Attention deficit hyperactivity disorder (ADHD) is a common neurodevelopmental disorder associated with adverse functional outcomes in children, adolescents, and adults [1]. Aside from the core inattention and hyperactivity/impulsivity symptoms, individuals with ADHD often exhibit persistent and incapacitating socio-emotional impairments, including emotion dysregulation and interpersonal problems [2–5]. The high prevalence of

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such difficulties in ADHD samples currently bolsters research into their potential causes. For instance, it is hypothesized that interpersonal problems in ADHD can, at least partially, be explained by a deficit or delay in the development of socio-cognitive processes [6]. A central component of these processes is the development of *mentalizing* capacities. Mentalizing is generally defined as the ability to attribute mental states (e.g., emotions, thoughts, intentions) to others as well as appraise behavior as being driven by mental states [7, 8].

A growing number of studies report mentalizing impairments in children and adults with ADHD, as evidenced by classic theory of mind (ToM) paradigms, such as false belief tasks or the Reading the Mind in the Eyes Test [9–12]. Systematic reviews of existing studies confirm lower performances on ToM tasks in ADHD samples compared to controls [13, 14]. However, these also emphasize that the current evidence base is scarce and reflects rather mixed findings, often biased by important methodological issues, such as small and heterogeneous clinical samples and the use of different ToM tasks across studies.

As mentalizing is usually thought of as a developmental acquisition reaching well into adolescence, a key question in ADHD relates to whether impairments can be observed at different developmental stages, especially beyond childhood. Indeed, stronger effect sizes can be observed in studies reporting mentalizing impairments in children with ADHD, with relatively weak evidence for mentalizing impairments in adults [14]. Interestingly, research into potential socio-cognitive impairments in adolescents with ADHD remains particularly scarce [14, 15]. This is somewhat surprising given that adolescence is a critical time for the development of social cognition [16, 17]. Moreover, adolescents with ADHD are especially prone to experience interpersonal difficulties, such as conflicts with peers and family, peer rejection, and social isolation [6, 18–21]. These concerns warrant further examination of the acquisition of socio-cognitive abilities in adolescents and young adults with ADHD.

It is important to consider that assessing social cognition in ADHD can be a challenging task. First, it is well documented that the neuropsychological profile of ADHD is particularly variable [22–24]. In fact, concomitant cognitive deficits and/or the presence of comorbid conditions can affect performance on standardized tests in ADHD samples [25]. For example, an ongoing debate questions whether mentalizing impairments could be specific to ADHD, or whether they could be better explained by neuropsychological (e.g., attention, executive functions) deficits often associated with the disorder [26, 27]. Remarkably, even though attention deficits are known to be highly prevalent in ADHD samples, very few studies looking into social cognition in ADHD include attentional measures [28, 29].

A second difficulty in assessing social cognition in ADHD concerns the tasks typically employed and their (lack of) ecological validity [30]. In an attempt to address this issue, the Movie for Assessment of Social Cognition (MASC) [31], was designed to provide a detailed examination of individual differences in mentalizing. This ecologically valid, computerized task proved to be useful in characterizing socio-cognitive profiles in clinical populations [32, 33] and in adolescents and adults from the general population [34, 35]. In comparison to classic ToM paradigms, the MASC offers two major advantages lying in the scoring procedure. First, apart from considering performance in terms of total scores, it allows to classify error types, such as under- or over-attribution of mental states, enabling to establish specific error patterns in different clinical populations. For example, several studies find that borderline personality traits are associated with the tendency to over-attribute mental states to others or "hypermentalize" [36–38]. On the other hand, increased prevalence of "no mentalizing" errors can discriminate between individuals with autism spectrum disorder (ASD) and typically developing controls [39, 40]. Second, the MASC allows to assess the attribution of different types of mental states, giving separate scores for intentions, thoughts, and emotions. For instance, we previously documented that in adolescents from the general population, self-reported attentional difficulties were particularly associated with lower scores on items that assess inference of intentions, as opposed to emotions [35].

Two recent studies involving adult participants compared MASC performance between ADHD and healthy control groups. Abdel Hamid et al. [41] found no differences in MASC scores between 30 treatment naïve adults with ADHD (mean age = 34.50 years, SD = 6.81) and an equal-sized group of healthy controls, matched for age, gender, IQ, and education level. Similarly, in a neuroimaging study, Mehren et al. [42] found comparable MASC performance and no structural brain differences between 26 adults with ADHD (median age = 31.00, IQR = 14.25) and 26 age- and gender-matched healthy controls.

Only one study to date has specifically examined mentalizing patterns with the MASC in adolescents with ADHD. Akça and colleagues explored relationships between ADHD and borderline personality disorder (BPD) symptoms and MASC scores in 550 adolescent inpatients, divided into three groups: those meeting diagnostic criteria for ADHD only (n = 69), BPD only (n = 116), and for both ADHD and BPD (n = 57) [43]. MASC scores were overall comparable between ADHD and BPD adolescents. Yet, based on regression analyses, the authors report that ADHD may be predominantly associated with hypomentalization errors, whereas BPD may be predominantly associated with hypermentalization errors. The interpretation of these findings merits caution, as the authors did not compare the scores of ADHD participants to those of a healthy control group. Moreover, as their sample included inpatient adolescents, most of these youths had comorbid psychopathology accompanying ADHD, which could have putatively impacted their performances on the MASC.

The primary objective of the present study is to compare mentalizing performance, as assessed by the MASC, between adolescents and adults with ADHD and healthy controls. Accordingly, we aim to provide direct evidence regarding developmental differences in mentalizing between adolescents and adults with ADHD. More specifically, based on the findings of Akca et al. [43] and reports of socio-cognitive impairments in children with ADHD, we hypothesized that adolescents, but not adults with ADHD would show a tendency to under-attribute mental states – evidenced by more hypomentalizing and/or no mentalizing errors, compared to controls. In addition, based on our previous results in community adolescents [35], we hypothesized that adolescents with ADHD would have more difficulties on items requiring inference of cognitive (intentions and thoughts), as opposed to affective (emotions) mental states. More generally, in agreement with the developmental literature, we expected to find age effects on mentalizing performance, irrespective of the diagnostic group, with adolescents consistently showing lower scores on the MASC than adults.

Our secondary objective was to examine potential associations between the severity of attention problems, as measured by the Conners' Continuous Performance Test (CPT-3™), and MASC scores in the ADHD group. Precisely, we hypothesized that the tendency to under-attribute mental states would be associated with the severity of attention problems. Moreover, we wanted to explore which dimensions of attention problems (inattentiveness, vigilance, impulsivity, sustained attention) may be particularly associated with mentalizing scores. Finally, we wanted to test whether the potential relationship between attention problems and mentalizing in ADHD is not better explained by comorbidity.

Materials and Methods

Design and Methodology

To address the first research question, a cross-sectional 2 × 2 between-group design was adopted, with diagnosis (ADHD vs. controls) and age group (adolescents vs. adults) as between-subjects variables. Control subject selection was restricted to the exact same number of participants as in the ADHD groups, and followed strict age and gender matching between the control participants and their respective ADHD adolescent and adult groups. To address the second research question, a cross-sectional correlational design was adopted, focusing on the correlates of MASC performance in the ADHD group only.

Participants

A power calculation was performed to estimate sample size, and based on previous literature comparing clinical and control groups on the MASC [44–47], we anticipated effect sizes within a medium range. With 80% power, the total sample size of at least 90 subjects was estimated to be adequate to detect medium-range effects (Cohen's f statistic at 0.30). The recruitment procedure and the inclusion criteria for each group are detailed below.

ADHD Subjects

Clinical data were acquired as part of an ongoing research project exploring social cognition in adolescents and adults with ADHD, conducted in our laboratory from year 2018. Adolescents with ADHD were recruited through advertisements for the research project in local parents' associations for children with ADHD and through collaborations established with local private practice child psychiatrists. Young adults with ADHD were recruited from a specialized outpatient ADHD clinic at the Geneva University Hospitals.

Inclusion criteria for the clinical group were age (12–17 or 19–33 years), fluency in French, and meeting current diagnostic criteria for ADHD (DSM-V). Exclusion criteria were history of psychotic disorders, BPD, ASD, or neurological disorders. All adolescents considered eligible for the study did participate. Among 29 eligible adults contacted by the research team, 23 (80%) agreed to participate. The final ADHD sample meeting inclusion criteria consisted of 26 adolescents (13 female, age range = 12–17 years, mean age = 14.89, SD = 1.63) and 23 young adults (8 female, age range = 19–33 years, mean age = 25.08, SD = 3.85).

Healthy Control Subjects

The control data were collected as part of a research project exploring relationships between mentalizing, as assessed by the MASC, and psychological functioning in adolescents and adults from the general population. For this project, participants were recruited from the community by undergraduate psychology students as part of their course requirements. Data were collected between 2015 and 2022. Control subjects were selected from our database of 131 adolescents and 140 adults who have completed the MASC during that project. This approach allowed to carefully match the clinical groups in terms of size, age, and gender. Thus, inclusion criteria established for the control counterpart of our clinical sample were age (12–17 or 19–33 years), gender (matching the ADHD group), fluency in French, and absence of prior or current psychiatric, neurodevelopmental, or neurological conditions. The selected control group consisted of 26 adolescents (13 female, age range = 12–17 years, mean age = 15.06, SD = 1.45) and 23 adults (8 female, age range = 19–33 years, mean age = 25.51, SD = 3.95) from the general population.

Procedure

ADHD Diagnostic Procedure

For the clinical group, ADHD diagnostic criteria were investigated by detailed anamnestic interviews and confirmed by well-established semi-structured interviews. For adolescent participants, the interviews were conducted with their parents using the ADHD Child Evaluation (ACE) [48]. For adults, they were conducted individually with the participants (ACE+ [49] or diagnostic interview for ADHD in adults (DIVA) [50]). As part of the diagnostic procedure, all subjects also underwent an objective evaluation of attention problems with the Conners CPT-3. Additionally, comorbidity status was recorded, defined as the presence or absence of additional psychiatric diagnoses at the time of the study. All diagnostic assessments were conducted by experienced clinical psychologists specialized in ADHD.

Experimental Protocol

ADHD and control subjects completed a single experimental session (90–120 min), during which they completed a series of standardized questionnaires and experimental tasks, including the MASC. The clinical and control protocols were comparable in length and in the number and type of tests administered. The experimental sessions were conducted by master's or doctoral-level psychology students or research assistants in the same laboratory at the University of Geneva. All experimenters received training and supervision by senior team members in order to guarantee a standardized administration of all tests. Participants with ADHD were asked to abstain from their psychostimulant medication 24 h prior to the study session.

Measures

The MASC [31] is a computerized task used to assess mentalizing. The French translation of the task, kindly provided by Dr. Patricia Garel, Dr. Linda Booij, and Dr. Catherine Herba (CHU Sainte-Justine, Montréal, Canada), was employed in this study (see French validation in [51]). The MASC consists of a 15-min movie featuring four characters interacting during a dinner party. The movie stops at different moments during the plot and participants are asked a multiple-choice question about the characters' mental states: intentions (e.g., "Why did Anna say that?"), thoughts (e.g., "What is Ben thinking?"), and emotions (e.g., "What is Mary feeling?"). In total, the task comprises 45 multiple-choice test questions, resulting in a maximum total score of 45 correct responses. For each question, four answer options are provided, each option reflecting either *correct mentalizing* (balanced attribution of mental states), *hypermentalizing* (tendency to over-interpret mental states), *hypomentalizing* (tendency to under-interpret mental states), or *no mentalizing* (absence of mental state attribution). Accordingly, four main scores for each mentalizing pattern are computed. Additional sub-scores are also calculated to categorize performance in terms of mental state type evaluated in each item. Nineteen items assess the inference of intentions, 8 items – inference of thoughts, and 18 items – inference of emotions. For the purpose of this study, we summed the scores of the intentions (/19) and thoughts (/8) items in order to obtain a single total score reflecting inference of cognitions (/27). This approach allows to distinguish between the inference of cognitive versus affective mental states, in line with current theoretical models [52]. Raw scores were used for the data analysis.

The Conners CPT-3 was used to assess the severity of attention problems in the ADHD group only. This computerized assessment is a widely used measure of attention-related problems in adolescents and adults. During this 14-min task, participants have to press the response key as soon as a target (letter) appears on the screen, but abstain from responding when the target is an "X." The CPT-3 provides 9 T-scores. A T-score is a conversion of a raw score to a standard score, representing its deviation from the mean of a normative sample, the mean being equal to 50 with a standard deviation of 10. The T-scores characterize performance in four dimensions of attention problems: inattentiveness, impulsivity, sustained attention, and vigilance. Higher T-scores reflect higher impairment on the task, compared to a normative sample. In this study, four T-scores were selected to specifically represent each domain of attention problems assessed. The detectability score (d'), reflecting the ability to discriminate between targets and no targets, was selected as a measure of inattentiveness. The rate of perseveration errors was selected as an index of impulsivity. The indicators of sustained attention and vigilance consisted of variables sensitive to participants' reaction time to targets (hit reaction time [HRT]). Specifically, sustained attention was assessed by an index of reaction time change between different blocks of the task (Block Change HRT), and vigilance was assessed by an index of reaction time change at various levels of stimulus frequency (HRT inter-stimulus interval [ISI] Change).

Statistical Analysis

To address the first research question, as a first step, we examined the effects of age group (adolescents vs. adults) and diagnostic group (ADHD vs. healthy controls) on the four main MASC scores. Separate 2 × 2 between-subjects analyses of variance (ANOVA) were conducted on the total MASC score (correct mentalizing) and on the error scores (hypermentalizing, hypomentalizing, no mentalizing). As typically seen in clinical samples, the variance of the scores was higher in the ADHD group, hence the homogeneity of variance assumption was violated. Nevertheless, we proceeded with the analysis of variance as all groups were comparable in size and the data were normally distributed. As a second step, we conducted post hoc ANOVAs on the MASC subscores obtained for cognitions and emotions in order to investigate potential between-group differences in the inference of different types of mental states. Partial eta squared (η_p^2) was used as an indicator of effect size, following Cohen's rule of thumb: $\eta_p^2 = 0.01$ reflects a small effect, $\eta_p^2 = 0.06$ indicates a medium effect, and $\eta_p^2 = 0.14$ indicates a large effect.

To address our second research question, in an exploratory fashion, we tested the hypothesized associations between MASC scores and attention problems in the ADHD sample. First, correlation analyses were performed in order to characterize relationships between the four main MASC scores and the CPT-3 scores in each domain of attention problems. Then, we computed linear regression models to test whether the relationship between the severity of attention problems and MASC scores would persist after including comorbidity status (presence vs. absence of additional diagnosis) as an another predictor. For ADHD adolescents, age was also included in the models to control for the variability in scores between younger and older adolescents.

Table 1. Demographic and clinical characteristics of the ADHD groups

	ADHD adolescents (n = 26)	ADHD adults (n = 23)	p value
Age, range	12–17	19–33	–
Age, mean (SD)	14.89 (1.63)	25.03 (3.85)	<0.001
Gender, F/M	13/13	8/15	0.28
ADHD subtype, n (%)			0.23
Inattentive	19 (73.1)	12 (52.2)	–
Hyperactive/impulsive	–	1 (4.3)	–
Combined	7 (26.9)	10 (43.5)	–
Comorbid diagnoses,[a] n (%)			
Specific learning disorders (dyslexia, dysgraphia, dyscalculia)	7 (26.9)	1 (4.3)	0.03
Depression	2 (7.7)	4 (17.4)	0.30
Anxiety disorders	1 (3.8)	2 (8.7)	0.48
Total	9 (34.6)	5 (21.7)	0.32
Psychostimulant medication,[b] n (%)	3 (11.5)	5 (21.7)	0.33
Antidepressant medication,[b] n (%)	2 (7.7)	2 (8.7)	0.89
Attention performance (CPT-3)			
Detectability d' T-score	53.65 (12.71)	50.00 (9.94)	0.27
Perseverations T-score	61.23 (18.89)	52.36 (12.67)	0.06
HRT Block Change T-score	56.38 (13.62)	53.23 (7.24)	0.33
HRT ISI Change T-score	64.19 (16.05)	50.82 (8.68)	<0.01

χ^2 tests and independent samples t tests were used to compare sample characteristics between adolescents and adults with ADHD, with the p values presented in the table. Compared to adults, adolescents with ADHD were more likely to have a specific learning disorder ($\chi^2(1, 49) = 4.55$, $p = 0.03$) and showed significantly higher impairment scores on the CPT-3 vigilance measure $t(47) = 3.56$, $p < 0.01$; mean difference = 13.37, CI 95% = [5.81, 20.93]. ADHD, attention deficit hyperactivity disorder; CPT-3, Continuous Performance Test 3rd version; d', detectability score; HRT, hit reaction time; ISI, inter-stimulus interval. [a]One subject can have more than one comorbid diagnosis. The total comorbidity score represents the number of subjects in each age group that had one or more additional diagnosis at the time of the study. [b]Number of participants who took medication on the day of the study. 7/26 (27%) adolescents and 18/23 (78%) adults had medication currently prescribed for their ADHD symptoms (methylphenidate, dexmethylphenidate, lisdexamfetamine, atomoxetine). However, all participants were instructed to abstain from their ADHD medication on the day of the experimental session, but 3 adolescents and 5 adults forgot to do so.

Correlations and regression models were conducted separately for adolescents and adults in order to account for potential developmental differences. Considering the exploratory nature of our research questions, we maintained the $p < 0.05$ threshold for significance in all analyses.

Results

Effects of Age Group and ADHD Diagnosis on MASC Scores in the Whole Sample

Demographic and clinical characteristics of adolescents and young adults with ADHD are presented in Table 1.

Total Correct Mentalizing Scores

For the total MASC scores, the ANOVA showed a main effect of age group ($F_{1,\ 94} = 20.15$, $p < 0.001$, $\eta_p^2 = 0.18$), with a large effect size. Overall, adolescents obtained lower MASC scores than adults (see Table 2). There was no main effect of ADHD diagnosis ($F_{1,\ 94} = 0.19$, $p > 0.1$) and no significant age × ADHD diagnosis interaction. Scores of subjects with ADHD were on average comparable to those of age- and gender-matched healthy controls. However, descriptively, we noted that the scores within the adolescent ADHD group tended to be more variable, compared to the control adolescent group (see Table 2).

Error Scores

The ANOVA showed a main effect of age group in hypermentalizing errors ($F_{1,\ 94} = 12.05$, $p < 0.01$, $\eta_p^2 = 0.11$), hypomentalizing errors ($F_{1,\ 94} = 5.47$, $p = 0.02$, $\eta_p^2 = 0.06$), and no mentalizing errors ($F_{1,\ 94} = 9.09$, $p < 0.01$, $\eta_p^2 = 0.09$). On average, adolescents obtained more errors than adults. There was no effect of ADHD diagnosis and no age × diagnosis interaction for hypermentalizing and

Table 2. Raw scores obtained on the MASC in subjects with ADHD and controls, by age group

	Adolescents		Adults		*p* value
	ADHD (*n* = 26)	controls (*n* = 26)	ADHD (*n* = 23)	controls (*n* = 23)	
MASC correct mentalizing					
Total (/45)	27.50 (7.05)	29.54 (3.32)	33.39 (2.76)	32.17 (4.17)	0.09
Cognitions (/27)	16.54 (4.70)	18.42 (2.32)	20.13 (2.18)	19.48 (2.64)	0.05
Emotions (/18)	10.96 (2.88)	11.12 (2.14)	13.26 (1.29)	12.70 (2.20)	0.42
MASC error scores					
Hypomentalizing (/45)	7.38 (3.50)	5.42 (1.88)	5.04 (1.80)	5.43 (2.17)	0.02
Hypermentalizing (/45)	7.12 (3.34)	8.04 (3.17)	5.26 (2.16)	5.87 (2.51)	0.79
No mentalizing (/45)	3.00 (2.64)	2.00 (1.79)	1.26 (1.01)	1.52 (1.24)	0.09

The table shows the means (and standard deviations) of MASC scores obtained by all participant groups. The *p* value represents the significance of the interaction term age group × ADHD diagnosis in the analysis of variance. $p < 0.05$ is the chosen threshold for statistical significance. ADHD, attention deficit hyperactivity disorder; MASC, Movie for Assessment of Social Cognition.

no mentalizing errors ($p > 0.5$). On the other hand, for hypomentalizing errors, results showed no main effect of ADHD diagnosis, but a significant age × ADHD diagnosis interaction ($F_{1,\ 94} = 5.58$, $p < 0.05$, $\eta_p^2 = 0.06$). Compared to controls, adolescents with ADHD obtained significantly more hypomentalizing errors. In contrast, the prevalence of hypomentalizing errors was comparable between ADHD adults and controls.

Inference of Cognitions versus Emotions

The post hoc ANOVA on the two MASC sub-scores revealed a main effect of age group on the scores reflecting inference of cognitions ($F_{1,\ 94} = 13.13$, $p < 0.01$, $\eta_p^2 = 0.12$) and emotions ($F_{1,\ 94} = 18.57$, $p < 0.001$, $\eta_p^2 = 0.17$). As before, adolescents scored significantly lower than adults, and we observed no main effects of ADHD diagnosis ($p > 0.05$).

For the inference of cognitions, the age × ADHD diagnosis interaction was at the threshold of significance ($F_{1,\ 94} = 3.91$, $p = 0.05$, $\eta_p^2 = 0.04$). Compared to controls, adolescents, but not adults with ADHD obtained slightly lower scores on items assessing attribution of cognitions (see Table 2). There were no interaction effects on the score of emotions ($p > 0.5$).

Associations between the Severity of Attention Problems and MASC Scores in the ADHD Group

Correlations

Pearson's correlations were conducted to examine the associations between CPT-3 and MASC scores in the ADHD group. In the adolescent ADHD group, the analysis revealed significant negative correlations between the MASC total score and the CPT-3 indices of inattentiveness (d'), impulsivity (perseverations), and vigilance problems (HRT ISI Change) (see Table 3). In line with this result, higher rates of hypomentalizing and no mentalizing errors were associated with higher impairment scores on these three measures. Hypermentalizing errors, on the other hand, were not associated with CPT-3 scores. Besides, the CPT-3 score of sustained attention (HRT Block Change) was not correlated to any of the MASC scores. No significant associations between CPT-3 performance and MASC scores were observed in the adult ADHD group.

Linear Models

Three models were computed to predict the conditional mean scores of correct mentalizing, hypomentalizing, and no mentalizing, respectively. Age was entered as a control variable in all three models. To avoid multicollinearity, we chose one CPT-3 score per model to reflect attention problems, based on the correlational analysis. Specifically, the CPT-3 scores that showed the strongest correlations with the dependent variables were entered as predictors in the respective models. Thus, the inattentiveness score (d') was chosen as a predictor of total MASC scores and hypomentalizing errors, whereas the vigilance score (ISI Change) was chosen as a predictor for no mentalizing errors. In all three models, comorbidity status (yes or no) was entered as an additional predictor.

The first model, with the total MASC score as a dependent variable ($F_{3,\ 25} = 6.11$, $p < 0.01$, $R^2 = 0.45$), showed that age and comorbidity status did not contribute to the model, whereas the CPT-3 detectability score ($b = -0.22$, SE = 0.06, $t = -3.72$, $p < 0.01$) significantly predicted total MASC scores. Similarly, in the second model ($F_{3,\ 25} = 4.90$, $p < 0.01$, $R^2 = 0.40$), the CPT-

Table 3. Correlations between MASC and CPT-3 scores in 26 adolescents with ADHD

	1	2	3	4	5	7	8	9
1. MASC total score	–	–0.711**	–0.786**	–0.729**	–0.618*	–0.493*	–0.376	–0.538**
2. Hypermentalizing		–	0.263	0.286	0.325	0.293	0.251	0.219
3. Hypomentalizing			–	0.442*	0.616**	0.400*	0.324	0.405*
4. No mentalizing				–	0.421*	0.415*	0.257	0.623**
5. CPT d'					–	0.827**	0.522**	0.397*
7. CPT perseverations						–	0.334	0.386
8. CPT HRT Block Change							–	0.424*
9. CPT HRT ISI Change								–

MASC, Movie for Assessment of Social Cognition; CPT, Continuous Performance Test; d', detectability score; HRT, hit reaction time; ISI, inter-stimulus interval. $p < 0.05$*; $p < 0.01$**.

3 d' score ($b = 0.11$, SE = 0.03, $t = 3.19$, $p < 0.01$) showed to be a significant predictor of hypomentalizing errors, whereas age and comorbidity status did not contribute to the model ($b = 0.727$, SE = 0.83, $t = 0.87$, $p > 0.1$).

Finally, the CPT-3 vigilance score ($b = 0.11$, SE = 0.03, $t = 3.83$, $p < 0.01$) showed to be a significant predictor of no mentalizing errors ($F_{3, 25} = 6.83$, $p < 0.01$, $R^2 = 0.48$). Age and comorbidity status did not significantly contribute to the model.

Discussion

The primary goal of this study was to compare mentalizing performance between adolescents and young adults with ADHD and matched healthy controls, using a valid, ecological task (MASC) to characterize mentalizing patterns. Our first hypothesis postulated that compared to controls, adolescents, but not adults with ADHD would show differences in performance on the MASC. We observed that adolescents with ADHD were more prone to make hypomentalizing errors, reflecting reduced mental state inference. Rates of no mentalizing errors in adolescents with ADHD were however not different from healthy controls. This finding could have important implications for understanding the differences in the socio-cognitive profile between ADHD and other clinical groups. For example, it has been questioned whether mentalizing impairments observed in ADHD are comparable in severity to those observed in ASD [12, 53]. Our results argue that hypomentalizing errors in ADHD are driven mostly by inattentiveness. In fact, responses reflecting concrete thinking and a complete absence of mental state reasoning were relatively rare in the ADHD group, similarly to controls. By contrast, recent studies reveal that individuals with ASD also show overall lower total scores on the MASC and higher rates of no mentalizing errors, reflecting a specific impairment of mentalizing abilities [40]. Alternatively, it is plausible that instead of reflecting a genuine hypomentalizing pattern, higher error rates documented in our adolescent ADHD sample were biased by comorbid difficulties. Specifically, adolescents in our sample had higher rates of specific learning disorders, which can also be associated with mentalizing impairments [54, 55]. However, our regression analyses showed that the relationship between attention deficits and hypomentalizing prevailed after controlling for age and comorbidity in the models. We incite future studies to address the independent effects of ADHD symptoms and comorbid conditions on MASC error types.

We further predicted that adolescents with ADHD would show overall lower scores on items requiring mentalizing cognitions versus emotions. Our present results demonstrated that adolescents with ADHD tended to have lower and importantly, more variable scores on items testing inference of cognitions, rather than emotions. From a theoretical perspective, we can imagine that one may need more attentional resources to pick up signs of others' hidden mental states, such as thoughts and intentions. On the other hand because of the salience of emotional stimuli, they would be harder to miss. However, poorer attentional control has been consistently linked to both cognitive and affective aspects of ToM [27, 56]. Future studies with larger samples are needed to clarify whether ADHD symptoms may interfere with the inference of some types of mental states more than others.

Interestingly, and in line with prior studies [41, 42], our results showed that in adults with ADHD, all MASC scores were comparable to those of healthy controls. This could be paralleled with the clinical course of ADHD and reports of improvements in some symptoms from childhood to adulthood [57, 58]. Our findings could be tentatively interpreted in light of the maturational delay hypothesis, suggesting that ADHD may be characterized by a developmental "lag" in the maturation processes between brain networks [59, 60] and the development of higher order neurocognitive abilities, including social cognition [60, 61]. Thus, the relative "immaturity" of neural networks implicated in social cognition, compared to age-matched controls, may result in a tendency to hypomentalize in adolescents. However, with age and the protracted neural development, this difference disappears.

An alternative, but not necessarily contradictory hypothesis is that our results could reflect a pattern of developmental vulnerability. In this vein, developmental neuroimaging studies suggest that mentalizing becomes more efficient with age. For example, functional connectivity studies show an increased integration between social cognition and cognitive control systems during performance of socio-cognitive tasks, suggesting a maturation of neurocognitive strategies [62]. Moreover, neural networks involved in attentional control and executive functions are maturing in parallel from adolescence to adulthood [63]. Therefore, attentional control difficulties as observed in ADHD may have more adverse effects on mentalizing abilities in adolescence, as these are still undergoing significant development [64, 65]. The positive correlations demonstrated between the severity of attention problems and hypomentalizing in our adolescents could further support this hypothesis. Perhaps in adults, on the other hand, the mentalizing process is already more integrated within the cognitive control system, and thus is less susceptible to be influenced by fluctuations in attention. Critically, the lack of evidence for differences in mentalizing performance in adults with ADHD further supports the idea of a delay or a vulnerability stage in adolescence, rather than a general deficit associated with ADHD. However, this interpretation is only speculative, given the small sample and the cross-sectional design of our study. In fact, recent evidence indicates that the developmental trajectories and persistence rates of ADHD are extremely variable both between and within individuals [66, 67], with a range of factors affecting the fluctuation of symptoms and associated impairments at different stages of development [68].

The secondary objective of this study was to explore whether the severity of attention deficits correlates with altered mentalizing in individuals with ADHD. We observed that in adolescents, but not in adults with ADHD, the prevalence of hypomentalizing and no mentalizing errors was most strongly correlated with the severity of inattentiveness and vigilance problems, respectively, after controlling for the presence of an additional diagnosis. In line with this result, prior studies showed that attention problems were associated with lower mentalizing scores in children with ADHD [26, 29]. For example, Mary et al. [26] found that lower performance on the RMET and the Faux Pas task was mediated by attentional and executive measures. In fact, when attentional and executive deficits were controlled for, mentalizing performance in children with ADHD was not significantly different from controls. We can speculate that inattention to mental state information may make it harder to consistently appraise various sources of information in a given social situation, possibly resulting in missing some relevant cues and hereby hypomentalizing. Indeed, it is well documented that attention plays an important role in the inference of goal-directed behavior and the development of social cognition [69, 70]. Moreover, mentalization theory identifies attentional control as one of the three building blocks of developing reflective functioning [71]. Accordingly, our results in adolescents with ADHD provide further support for the hypothesis that mentalizing impairments documented in ADHD could be developmentally intertwined with inattention mechanisms inherent to the disorder.

Limitations and Future Perspectives

This study had a number of methodological limitations, sparking ideas for improvements in future research. For instance, a major limitation is the small sample and the related precaution to not adjust *p* values in the analyses, which calls for replication of our results in larger studies. Besides, we did not examine gender effects, whereas previous reports highlight gender differences on the MASC [34, 43]. Knowing that socio-emotional impairments can vary between boys and girls with ADHD [72, 73], the question of gender differences in the socio-cognitive profile of ADHD merits further attention. Another limitation is the lack of any objective measures of attentional control in the healthy control comparison group. Comparing correlates of performance both in ADHD and healthy controls would help to understand whether the same psychological mechanisms are involved in adaptive social cognition development in ADHD and in typical development. Indeed, similarities and differences in the trajectories of socio-cognitive development between ADHD and their healthy control counterparts remain to be clarified. Finally, we did not investigate the effects of medication on performance, as we asked participants to abstain from medication on the day of the study and only a small proportion of our ADHD sample forgot to do so. However, medication effects are important to elucidate in future studies. In fact, if hypomentalizing is a result of inattentiveness, it is possible to hypothesize that medication effects on core ADHD symptoms could also improve attentional capacities in social situations [74]. Moreover, given that medication nonadherence is common in adolescent ADHD [75, 76], it is important to explore the effects of nonpharmacological treatment alternatives targeting mentalizing abilities in young people with ADHD [77].

We encourage future research to address the aforementioned aspects in carefully designed experimental protocols. This can be achieved by choosing ecological experimental tools that provide clinically relevant information (e.g. error types) and by paying closer attention to individual factors that can affect scores, including core behavioral symptoms, cognitive deficits, and comorbid conditions. Longitudinal designs tracking individuals from childhood to adulthood are essential for clarifying the developmental trajectory of mentalizing in ADHD. It is important to clarify which youths with ADHD are more (or less) vulnerable to develop mentalizing difficulties and possibly, related emotion regulation and interpersonal problems. In addition, neuroimaging studies are needed to compare the neural correlates of mentalizing performance in ADHD throughout development.

Conclusion

In summary, this study demonstrated that adolescents, but not adults with ADHD, can show a tendency to underattribute mental states to others, which was positively associated with the severity of their attention problems. This indicates that mentalizing and attentional capacities entertain a significant clinical association in adolescence. These findings encourage further inquiry into the development of mentalizing capacities in ADHD, particularly in adolescence and the transition to adulthood.

Statement of Ethics

The clinical study protocol was reviewed and approved in 2019 by the Swiss Ethics Committee (BASEC ID 2019-00795 grant awarded to the PI), whereas the control data collection was reviewed and approved in 2015 by the University of Geneva Ethics Committee (Faculty of Psychology and Education Sciences). Written informed consent was obtained from all participants (and their parents for underage subjects).

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Funding Sources

The PI (Martin Debbané) was funded by the Swiss National Science Foundation (Grant No. 100014_179033), as well as the Marina Picasso Prize from the AEMD Foundation 2018. The funders had no role in study design and data collection, analysis, or interpretation.

Author Contributions

Elena Poznyak contributed to the conceptualization, methodological design, data collection and analysis, and wrote the original draft of this paper. Jessica Lee Samson, Juan Barrios, Halima Rafi, and Roland Hasler contributed to data collection and to the validation of the manuscript. Nader Perroud supervised the research project and contributed to the interpretation of the work and the revision and editing of the manuscript. Martin Debbané led the research project and contributed to the conceptualization, funding acquisition, and writing and revision of the manuscript; he also approved the final version.

Data Availability Statement

Data used in this study can be made available by the corresponding author upon written request, as the authors have no legal or ethical restrictions to share collected data in an anonymized format.

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