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Homogeneous or Heterogeneous I.Q Profile: Some Clinical Characteristics to Differentiate High Intellectual Potential and Asperger's Syndrome in Children

Laurence Vaivre-Douret[1, 2,3,4,5,*], Pascale Planche[6,7]

[1]Faculty of Health, Division of Medicine Paris Descartes, Université de Paris, France

[2]National Institute of health and Medical Research (INSERM UMR 1018-CESP), Faculty of Medicine, University of Paris-Saclay, UVSQ, Villejuif, France

[3]University Institute of France (Institut Universitaire de France, IUF), Paris, France

[4]Department of Child Psychiatry, Assistante Publique-Hôpitaux de Paris (AP-HP.Centre), Necker-Enfants Malades University hospital, Paris, France

[5]Department of Endocrinology, IMAGINE Institute, Necker-Enfants Malades Université de Paris, France

[6]CREAD (EA3875), Centre de Recherche sur l'Education, les Apprentissages et la Didactique, France

[7]E-mail : pascale.planche@univ-brest.fr ; Université de Brest, France

***Corresponding Author:** Professor Laurence Vaivre-Douret, PhD, Hôpital Universitaire Necker-Enfants Malades, INSERM UMR 1018-CESP, Carré Necker Porte N4,149, rue de Sèvres, 75015 Paris, France, Tel : +33 (0) 1.44.49.40.14; Email: laurence.vaivre-douret@inserm.fr

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Abstract

Background: Some recent studies suggested that the homogeneous versus heterogeneous psycho-cognitive profiles established by the Wechsler scales are relatively good predictors of the behavioral characteristics and general adaptive abilities of children with high intellectual potential (HIP). First, the present study aimed to test the hypothesis that the heterogeneous IQ profile can be linked to social, behavioral and emotional difficulties in children with HIP. Secondly, by comparing HIP children and children with Asperger's syndrome combined with HIP, our purpose was to identify possible clinical characteristics to differentiate these profiles.

Materials and Methods: We carried out a comparative study between HIP children with a homogeneous IQ profile, HIP children with a heterogeneous IQ profile, children with an Asperger's syndrome combined with HIP and children with typical development. A total of 62 children, aged between 7 years and 7 months and 15 years and 11 months, were recruited for this research. The WISC-IV was used to identify children with HIP. Appropriated tests were used to assess respectively, social cognition and emotional adaptation, the visuoperceptual and visuomotor functions and the prevalence of anxiety and depressive disorders.

Results: The existence of links were confirmed between profile configuration and the interactional abilities of HIP children. Certain registers of social cognition and affectivity could represent possible indicators for distinguishing very high-functioning Asperger's syndrome and HIP without Autism Spectrum Disorders.

Conclusion: HIP children with a very heterogeneous IQ profile and considerable social and emotional difficulties are at high risk of being children with Asperger's syndrome.

1. Introduction

It is broadly accepted that the term "High Intellectual Potential" (HIP) refers to individuals obtaining a Full-Scale Intellectual Quotient (FSIQ) at least two standard deviations (SDs) above the average FSIQ of their peers of the same chronological age (i.e. an FSIQ equal to or higher than 130) in a psychometric test. The Wechsler scales are currently the most widely used measure for this assessment. While a FSIQ evaluation is a necessary condition for identifying HIP, it is not a comprehensive measure. A HIP classification should be based on a multidimensional quantitative and qualitative assessment that provides an understanding of how the person uses their functional resources in the affective, cognitive and social domains to react and adapt to their environment [1]. It also seems important to examine the motor and perceptual domains, which are often neglected in favor of the intellectual domain, in order to better understand the HIP profile [2].

These functional characteristics do not appear with the same intensity across the entire population of children with HIP. There is great variability in their manifestation. The profiles obtained using index scores from psychometric scales reflect either a homogeneity of performance in the functions investigated or a marked heterogeneity, suggesting underlying functions that may differentiate from day to day.

Recent studies have shown that the abilities profile established by Wechsler-type psychometric tests may be an indicator of a child's adaptive functioning. For example, the more heterogeneous the profile, the greater the risk of adaptation and/or learning difficulties [2-6]. The primary objective of this study was to compare children with HIP characterized by a homogeneous profile, children with HIP characterized by a heterogeneous profile and children with typical development. Our aim was to better understand the specific features and behavioral consequences of the

profiles derived from the Wechsler Intelligence Scales assessments in order to test this hypothesis of a link between profile configuration and adaptive abilities.

The psycho-cognitive assessment of the children in our study was carried out using the WISC-IV (Wechsler Intelligence Scale for Children, 4th edition, for children aged 6 to 16 years and 11 months, published in its French version in 2005). WISC-V was either not available to the research team or not yet published at the time of these assessments. This psychometric scale is used to evaluate FSIQ, which gives a general level of cognitive ability and index scores that can be interpreted to refine understanding of a test subject's cognitive functioning. The WISC-IV offers four index scores: The Verbal Comprehension Index (VCI), the Perceptual Reasoning Index (PRI), the Working Memory Index (WMI) and the Processing Speed Index (PSI).

The size of the dispersion of the inter-index scores shows the homogeneity or heterogeneity of the profile and impacts the FSIQ's diagnostic reliability. The smaller the dispersion between the lowest and highest index scores, the more homogeneous the profile and the more representative the FSIQ is as an indicator of the subject's general cognitive ability. The larger the dispersion, the more the profile reveals "strengths" and "weaknesses" within the intelligence components and the more limited the FSIQ's interpretive value. In this type of comparative study, it therefore seems pertinent to establish the dispersion threshold between the highest and lowest index scores for determining profile homogeneity or heterogeneity.

The current versions of the Wechsler Scale were designed to assess a set of distinct cognitive abilities. The relative independence of these abilities [7] results in the intra-individual variability in performance that has become common in these tests. This known variation is in the order of 7±2 points between the subtests and 23±10 points between the index scores [8]. The variability between the index scores is more reliable than that between the subtest scores in terms of determining profile homogeneity or heterogeneity [8, 9]. We therefore used index score variability to distinguish our groups of children with HIP.

The median range (WISC-IV and -V) varies between 20 and 23 points in regard to the maximum difference between indices. For any given index comparison, only 8–18% of subjects (depending on the indices) will present a difference of 23 points. However, when all the indices are included in the comparison, 52.8% of subjects will reach 23 points, and less than 5% of profiles will reach 43 points [8, 10, 11]. Some authors have suggested that the difference between the highest and lowest indices should be set at 23 points or higher to identify significant disharmony [12, 13]. However, even with this threshold, they proposed that the FSIQ should be considered a valid indicator for identifying HIP. We therefore used the threshold of 23 points to determine the homogeneity or heterogeneity of the profiles of the participants in our study.

Based on studies already carried out on children with HIP, we hypothesized that the domains most likely to differentiate them, depending on their profile configuration (homogeneous versus heterogeneous), were affectivity (in particular, emotional function), social cognition and motor skills. Janos and Robinson's [14] literature review, which spanned a period of six decades, showed that 20–25% of children with HIP present social and emotional difficulties. While the homogeneity of the diagnostic procedure may be questioned when considering a large body of work over such a long period, this singular population has often still been described in the literature as exhibiting an anxious hypersensitivity or hypervigilance with respect to their environment. Children with HIP are reported to show considerably more intense emotional reactions than children of the same age with typical development [15]. A sharper grasp of the information received both from their environment and from themselves is thought to give them a hyper-acuity that proves to be a source of anxiety for them [2, 16]. More often anxious and socially isolated than their peers with typical development, children and adolescents with HIP present more social, behavioral and emotional difficulties [3, 17, 18]. However, the research on anxiety in children and adolescents with HIP is contradictory. Some studies show they present more anxiety compared with a control group, and others not [19]. Martin et al. [20] concluded from their meta-analysis that anxiety and depressive symptomatology was less common in children and adolescents with HIP than in their peers with typical development. As suggested by Peyre et al. [21], it appears that this apparent association between high IQ and emotional symptoms is more likely to be found in individuals who present specific characteristics. Moreover, in Vaivre-Douret's [18] recent study, anxiety appeared to be associated with other symptoms of depression, which is significantly correlated with specific learning disorders (i.e. dyslexia and dyspraxia) that are often undiagnosed. Could this comorbidity of psycho-affective disorders be more frequent in children with HIP and a heterogeneous profile?

In addition, behavioral, communication and interactional difficulties have sometimes been described in some children with HIP. This is especially the case for the school environment because these social interaction difficulties can inhibit the children's use of their cognitive potential and result in academic failure. It is nevertheless important to stress that having high cognitive potentialities is more of an asset than a drawback and that it does not therefore inevitably lead to disrupted schooling within the education system. The questions raised here are whether the children who manifest proven socialization and communication disorders are characterized by a very heterogeneous performance profile in psychometric tests and whether an association with the socio-emotional disorders that disrupt daily interactions with other individuals might suggest a differential diagnosis of borderline Asperger's syndrome for some of these individuals?

Indeed, some children with HIP and some diagnosed with Asperger's syndrome combined with a FSIQ greater than or equal to 130 (AS/HIP) appear to present common clinical signs [4, 22]. Generally, these are social interaction disorders, restricted and over-invested interests, sensory modulation disorders, attentional disorders and praxis disorders.

Some clinicians are beginning to examine the results of studies on HIP and Asperger's syndrome from a developmental and psychopathological perspective and questioning a possible trans-nosographic continuum between these two clinical entities [23]. Social integration and interactions with others are complicated or even impossible for children with Asperger's syndrome and sometimes, as already mentioned, for those with HIP. Nevertheless, the current tendency to confer an Asperger's diagnosis on every individual assessed as having HIP, a very heterogeneous profile and socialization and/or learning disorders is probably excessive. It is not easy for a clinician to establish a differential diagnosis between HIP and Asperger's syndrome. Hence, a complementary objective of this study was to analyze the variables from psycho-clinical tests in order to identify, in the profiles of children with HIP, possible indicators of Asperger's syndrome with a view to facilitating its diagnosis and appropriate support decisions.

The criteria and methods for diagnosing autistic syndrome were updated in the DSM-5 [24], which proposes a dimensional approach with its introduction of the notion of *spectrum* to take into account the degrees of severity of the disorders (Autism Spectrum Disorders (ASDs)).

The previous nosographic categories "Pervasive Developmental Disorder – Not Otherwise Specified" (PDD–NOS) and "Asperger's Syndrome" (AS) were dropped in this latest edition of the DSM. Individuals diagnosed with PDD-NOS or Asperger's syndrome are now recategorized under ASDs if they meet all of the criteria or under "Communication Disorders" if criterion B (restricted and repetitive patterns of behavior, interests and activities) is absent from the symptomatology.

However, for the purposes of this study, we will retain the Asperger's syndrome diagnosis based on the ICD-10 criteria [25], which is still in use today. According to this classification, individuals with Asperger's syndrome have neither delayed cognitive development (their FSIQ is at least 70) nor language delay (first words appeared before the age of two and first phrases before the age of three). They are also characterized by qualitative anomalies in reciprocal social interaction, communication disorders and restricted and stereotyped behaviors, interests and preoccupations.

Motor clumsiness has often been associated in the literature with Asperger's syndrome, although findings have been mixed. Compared with children with typical development, some motor delays and coordination deficits have been observed in subjects with high-functioning autism with or without initial language delay [26-29]. Other authors [30, 31] have observed a higher rate of motor difficulties (clumsiness, manual dexterity difficulties, difficulties in fine and global coordination, etc.) in individuals with Asperger's syndrome, although these differences were not maintained with age [32-34].

Children identified as having HIP with a homogeneous IQ profile have shown advanced maturation of their neurosensorimotor functions between the ages of 0 and 36 months [2, 6, 35, 36]. This advanced maturation manifested without specific stimulation. However, school-aged children with HIP presenting for a clinical consultation have frequently been described as clumsy compared with their peers with the same level of functioning. This clumsiness fosters a dyssynchrony between the children's cognitive functions and their psychomotor and affective functions [37]. Why is the advanced maturation observed in these functions during the children's early years not maintained as they grow older? One possible answer is that the populations are different. There is indeed a clinical consultation bias, child consultants are likely to be characterized by a heterogeneous psycho-cognitive and motor profile. It therefore appears interesting to assess with a multidimensional clinical investigation our different samples to reveal possible points of similarity or difference.

By comparing children characterized by homogeneous-profile HIP, heterogeneous-profile HIP, Asperger's syndrome and typical development, we hope to provide some answers to the following questions. Are there socio-cognitive, affective and motor differences between these populations that would allow us to establish a precise differential diagnosis between them? In which function(s) do these differences manifest? Do children with a heterogeneous-profile HIP have a closer semiological proximity to children with Asperger's syndrome than those with a homogeneous-profile HIP, and, if so, in which functional domain(s)?

2. Materials and Methods

2.1 Participants

A total of 62 children aged from 7 years and 7 months to 15 years and 11 months were recruited for this research. In order to build different samples, the children with Asperger's syndrome combined with HIP were recruited from neuropsychological assessment and treatment centers and Centres de Ressources Autisme in the Ile de France and Brittany areas, and the children with HIP and those with typical development were recruited from private schools in Paris (classes specifically for children with HIP, mixed classes of children with typical development and children with HIP).

Although our intention was initially to recruit quantitatively equivalent groups, we found that the "random" recruitment of children who had been previously assessed by clinicians and identified as having HIP (FSIQ ≥130, see below inclusion criteria) made it extremely difficult to find children with HIP and a homogeneous profile because they were generally absent from clinical structures. Children with a heterogeneous profile made up the vast majority of the HIP population presenting for consultation (either in the various clinical structures or with private psychologists) for various disorders and/or a general lack of wellbeing. In addition, we found that the majority of children in the school classes specifically for children with HIP presented a heterogeneous profile. This first observation at least partly confirms one of our hypotheses. Moreover, children who combined Asperger's syndrome and HIP were rare, and the recruitment age for our study made it difficult to include them because Asperger's

syndrome is generally diagnosed at a later stage. All parents and children gave their written informed consent in accordance with the Declaration of Helsinki. All procedures of the study were approved by the local ethics committee of Paris Descartes University, Sorbonne Paris City (IRB: 00012019 – 49).

2.2 Study procedure and group selection

Selection of the "children with HIP" groups was based on an FSIQ assessment conducted by a clinical psychologist and/or a clinical neuropsychologist.

The participants were divided into four groups according to the following criteria:

1. Children with HIP and a homogeneous profile (HIP/HO):

- 13 children aged from 8 years and 11 months to 13 years and 7 months (mean age: 11.8 ± 1.5 years), 6 boys and 7 girls.

Inclusion criteria:

- FSIQ was greater than or equal to 130, and the difference between the highest and lowest index scores on the WISC-IV was ≤ 23 points. The mean difference was 18.15 (σ = 4.30; range 8–23).

Exclusion criteria:

Presence of a motor disability that was accidental/lesional in origin or of a proven genetic, neurological or organic pathology.

- Presence or past of psychiatric disorders/problems
- Psychoactive medication
- Deafness or blindness.

2. Children with HIP and a heterogeneous profile (HIP/HE):

- 24 children aged from 7 years and 7 months to 15 years and 10 months (mean age: 10.10 ± 2.5 years), 14 boys and 10 girls.

Inclusion criteria:

- FSIQ was greater than or equal to 130, and the difference between the highest and lowest index scores on the WISC-IV was greater than 23 points. The mean difference was 43.63 (σ = 10.92; range 25–62). The difference between the means of the HIP/HO and the HIP/HE was very significant (t=8.038, p<.0001).

Exclusion criteria:

- Presence of a motor disability that was accidental/lesional in origin or of a proven genetic, neurological or organic pathology.

- Presence or past of psychiatric disorders/problems
- Psychoactive medications
- Deafness or blindness.
- Performance profile in which one or more index scores was greater than 130 and the FSIQ was lower than 130.

3. Children with typical development (control group):

- 20 children with typical development and being educated in a typical environment, aged from 7 years and 7 months to 15 years and 9 months (mean age: 11.2 ± 2.6 years), 10 boys and 10 girls.

Exclusion criteria:

- Developmental delay or disharmony.
- Presence of one or more learning disorders.
- Presence of behavioral or psychopathological disorders identified by teachers and noted in anamnesis.
- Psychoactive medications
- Jumping or repeating a grade.
- Family history of ASD.
- Family history of serious psychiatric disorders.
- Presence of a motor disability that was accidental/lesional in origin or of a proven genetic, neurological or organic pathology.
- Presence or past of psychiatric disorders/problems
- Deafness or blindness.

4. Children diagnosed with Asperger's and characterized by a HIP (AS/HIP):

- 5 children aged from 8 years and 9 months to 15 years and 11 months (mean age: 11.10 ± 3 years), 5 boys.

Inclusion criteria:

- Diagnosis of an Asperger's syndrome-type "Pervasive Developmental Disorder" made in a Centre de Ressources Autisme or in a hospital by a child psychiatrist.
- Children included in the study were assessed with ADI-R [38] and ADOS-2 [39].
- No evidence of language delay according to the ADI-R criteria: 1st single words before 24 months and 1st phrases before 33 months.
- FSIQ greater than or equal to 130, as evaluated by the WISC-IV.

Exclusion criteria:

- History of language delay.
- ADHD
- Presence of a motor disability that was accidental/ lesional in origin or of a proven genetic, neurological or organic pathology.
- Presence or past of psychiatric disorders/problems
- FSIQ < 130 using the WISC-IV
- Psychoactive medications
- Deafness or blindness.

The assessments chosen for the data collection were presented in a dual relationship with the child and in a calm setting.

2.3 Assessment tools

2.3.1: To assess the FSIQ and establish the psycho-cognitive profile: A psychometric test: The WISC-IV, standardized for a French population aged from 6 years to 16 years and 11 months, was used to identify children with HIP.

2.3.2 To assess social cognition and emotional adaptation: Parents completed two questionnaires that were originally developed by Baron-Cohen and colleagues [40-42]. The French versions were validated by Sonié et al. [43, 44] and recommended by the French National Authority for Health for the fourth Autism plan (2018-2022): 1. One questionnaire measured the Empathy Quotient (EQ). The maximum EQ score was 80 points. The lower the score, the more it deviated from the mean for children with typical development (m=37.7; SD=9.81) and approached the norm for children with autism (m=13.97; SD=6.82); 2. One questionnaire measured the Autism Quotient (AQ). This comprised five subscales: Communication, Social competence, Imagination, Local details and Attention switching. The minimum AQ score was 0 points, the maximum 50. The maximum score for each of the five subscales was 10 points. The higher the scores, the further they deviated from the norm for children with typical development. The total mean AQ score was 12.13/50 (SD=5.55) for typical children and 35.06/50 (SD=7.46) for children at risk of ASD [45, French norms].

2.3.3 To explore visuomotor and visuoperceptual functions: Two tests were used: 1. The visuoperceptual VMI [45]: The task consisted of 30 items (principal functions engaged: perception/visual discrimination, oculo-motricity, visual working memory). Materials: Sheets of paper containing boxed 2D geometric shapes (target shapes). Below each target shape were similar shapes arranged in columns, with only one identical to the target shape. The child had to point to the shape that was identical to the shape in the box. 2. The visuomotor VMI [45]: This test identified significant difficulties in the integration or coordination of visuoperceptual and motor skills. Materials: Sheets of

paper, each containing three 2D geometric figures (models) printed in black and presented in landscape orientation. There were 24 figures in total. Test: Using a pencil, the child had to reproduce the geometric shape as accurately as possible in the space just below the model without using an eraser (principal functions engaged: visual perception, graphomotricity, motor control, visuomotor coordination). The figures they had to copy ranged from simple drawings (lines) to more complex figures representing 3D objects (cube). Grading: The child's output was graded according to strict criteria (respect for proportions, spatial links between different elements, angles, etc.).

2.3.4 To explore the prevalence of anxiety and depressive disorders: The MDI-C (Multiscore Depression Inventory for Children, [46] was used. This is a self-report questionnaire that is completed by the child. It provides insight into the child's emotional world and more specifically assesses possible depression through eight dimensions. Standardized for children and adolescents aged between 7 and 17 years, it produces a depression score, according to age-group and sex norms, and its possible severity (low to moderate, moderate to severe) as well as a profile of the various significant symptoms comprised in the score (Self-esteem, Anxiety, Sad mood, Social introversion, Pessimism, Provocation, Low energy, Instrumental helplessness). The standardized scores of the MDI-C range from 25 to 80 points. A standardized score between 56 and 65 corresponds to a mild to moderate depressive state. A standardized score between 66 and 75 reflects a moderate to severe depressive state. A score above 75 shows severe symptomatology.

2.4 Statistical analysis

Data analysis was performed using JASP statistical software (version: 0.11.1/October 7, 2019). First, the clustering method (K-means Clustering classification method) confirmed the homogeneity of each of the two groups of children with HIP established on the basis of the threshold of 23 points difference between the lowest and the highest index scores obtained in the WISC-IV.

Our analysis of the results then consisted of comparing (Independent Samples T-Test, ANOVA, χ^2) the performances of the previously defined groups in each of the functions for which data were collected (social cognition, visuomotor and visuoperceptual functions, anxiety and depressive disorders) in order to identify statistically significant differences between them (at the threshold of $p \leq .05$) and find correlations (Pearson's r). We also included the effect size whenever it was useful for a better interpretation of our data. Systematically we used the Levene's test to check the equality of variance and when it was significant ($p < .05$) suggesting an assumption of unequal variance, we used the Welch approach. Furthermore, we used the Bonferroni correction to adjust the observed significance level for the fact that multiple comparisons were made when it appeared necessary.

3. Results

3.1 Comparative analysis of the performances of the HIP groups without ASD (homogeneous profile and heterogeneous profile) and the control group

Group characteristics: One sample of 37 children with HIP (mean age = 11.2 ± 2.2 years; 20 boys and 17 girls) with mean FSIQ = 140.08 (SD=6.28). One control group sample of 20 children (mean age: 11.2 ± 2.6 years; 10 boys and 10 girls), who were all being schooled in their age group.

	HIP	**Control**	**t-test**	***p* value**	***Cohen's d***
AQ total	21.919 (8.836)	11.900 (5.730)	4.568	<.001	1.2
Communication	3.459 (2.456)	1.850 (1.785)	2.835	.007	.75
EQ total	33.865 (13.300)	40.050 (8.846)	-2.098*	.041	-.54
Social competence	4.027 (2.555)	1.300 (1.418)	4.409	<.001	1.2

* Levene's test was significant (p<.05) for the EQ-test suggesting an assumption of unequal variance, so we used the Welch t-test

Table 1: Mean scores (standard deviations) of HIP group versus control group in the social cognition function.

In the social cognition function, as shown in **Table 1**, the children with HIP obtained a higher mean score than the control group children in the AQ test (p<.001). They seemed to have more difficulties in the areas of communication, empathy and social skills (respectively p=.007; p=.041, p<.001). The other subscales of the AQ test, Imagination, Local details and Attention switching, are discussed below in the paragraph on the psycho-cognitive function.

	HIP	**Control**	**t-test**	***p* value**	***Cohen's d***
MDI-C total	52.676 (8.104)	44.850 (6.226)	3.755	<.001	1.04
MDI-C sad mood	53.811 (8.452)	47.350 (5.733)	3.417*	.001	.89
MDI-C anxiety	54.162 (7.555)	46.100 (7.725)	3.815	<.001	1.05

*Welch t-test

Table 2: Mean scores (standard deviations) of HIP group versus control group in the anxiety-depression function.

In the anxiety-depression function (**Table 2**), the children with HIP obtained a higher mean score than the control group (p<.001) in the total depression scale (although this score did not reach the clinical threshold indicative of a proven depressive state), the anxiety scale (p<.001) and the sad mood scale (p=.001). The other subscales (self-esteem, social introversion, pessimism, provocation, low energy, instrumental helplessness) did not significantly differentiate the groups.

	HIP	Control	t-test*	*p* value	*Cohen's d*
Visuoperceptual	**109.541 (**15.018)	**103.400 (**7.728)	2.038	.046	.51
Visuomotor	**108.757** (15.648)	**101.850 (**4.082)	2.530	.015	.69

* Levene's test was significant (p<.05) for these scales suggesting an assumption of unequal variance, so we used the Welch t-test

Table 3: Mean scores (standard deviations) of HIP group versus control group in the visuoperceptual and visuomotor functions.

In the visuoperceptual and visuomotor functions (**Table 3**), performance was average for all the children. However, the performances of the HIP group were significantly higher than that of the control group (p=.046, p=.015). The children with HIP showed a better mastery of the tasks.

	HIP	Control	t-test	*p* value	*Cohen's d*
Imagination	**3.270 (**2.156)	**1.850 (**1.226)	3.170*	.002	.81
Local details	**6.595 (**2.179)	**3.850 (**2.681)	4.183	.001	1.12
Attention switching	**4.541 (**2.479)	**3.050 (**1.791)	2.371	.021	.68

Reminder: the maximum score was 10 points for each of the AQ subscales. The higher the scores, the more they deviated from the norm for children with typical development.

*Levene's test was significant (p<.05) for the imagination subscale suggesting an assumption of unequal variance, so we used the Welch t-test.

Table 4: Mean scores (standard deviations) of HPI group versus control group in the psycho-cognitive functions (explored through the AQ test subscales).

In the psycho-cognitive functions, which were explored through the AQ test subscales (**Table 4**), the children with HIP consistently obtained higher mean scores than the control group, which would imply that these children had less imagination potential (p =.002) and less attention switching (p=.021) when processing information and that they took less account of local details compared with children in the control group (p =.001).

3.2 Comparative analysis of the performances of the HIP/HO, HIP/HE and control groups

Group characteristics: One sample of 13 HIP/HO children (mean age = 11.8 ± 1.5 years; 6 boys and 7 girls) with mean FSIQ = 141.30 (SD=6.81). One sample of 24 HIP/HE children (mean age = 10.10 ± 2.5 years; 14 boys and 10

girls) with mean FSIQ = 139.41 (SD=6.01). One sample of 20 control group children as previously described. There was no significant difference between the FSIQ scores of the two samples of children with HIP (t=-0.872, p>.05).

The objective of this comparative analysis was to differentiate the influence of the profile (homogeneous versus heterogeneous) of the children with HIP on their scores in the various tests proposed.

	HIP/HO	**HIP/HE**	**t-test**	***p* value***	***Cohen's d***
WISC-IV PRI	131.00 (5.354)	128.04 (10.732)	-0.962	>.05	-
WISC-IV PSI	**123.61** (8.723)	**112.00** (16.519)	-2.353	.024	-.81
WISC-IV WMI	**128.30** (9.707)	**115.75** (9.538)	-3.800	<.001	-1.30
WISC-IV VCI	**134.84** (9.822)	**148.50** (5.421)	5.478	<.001	1.88

*Significant differences appear in bold.

Table 5: Mean scores (standard deviations) of HPI/HO group and HPI/HE group obtained from the WISC-IV index scores.

First, a comparison of the mean scores obtained from the WISC-IV index scores was carried out (**Table 5**). This revealed significant differences between the two HIP groups. The children in the HIP/HO group showed better skills in working memory (p<.001) and information processing speed (p=.024). The HIP/HE children obtained a significantly higher mean score in the area of verbal comprehension than the HIP/HO children (p <.001). There was no significant difference between the two groups in the area of perceptual reasoning (p>.05).

	HIP/HO	**HIP/HE**	**Control**	**t-test**	***Pbonf** *
AQ total	18.308 (7.729)	**23.875 (**8.926)	**11.90 (**5.730)	5.160	<.001
Communication	2.308 (1.974)	**4.083 (**2.501)	**1.850 (**1.785)	3.420	.004
EQ total	38.462 (10.898)	**31.375 (**14.018)	**40.050 (**8.846)	-2.494	.044
Social competence	3.231 **(**2.088)	**4.458 (**2.718)	**1.300** (1.418)	4.750	<.001

*Significant differences appear in bold. The Bonferroni correction was used to adjust the observed significance level

Table 6: Mean scores (standard deviations) of HIP/HO and HIP/HE groups versus control groups in the social cognition function.

In the social cognition function **(Table 6**), there were no significant differences between the HIP/HO and HIP/HE groups. However, in each of these registers, the HIP/HE group showed significantly more difficulty than the control group in social skills (P*bonf*<.001), communication skills (P*bonf* =.004) and empathy (P*bonf* =.044) as well as higher mean scores in the AQ test (P*bonf* <.001).

	HIP/HO	**HIP/HE**	**Control**	**t-test**	***Pbonf*** *****
MDI-C total	51.462 (8.130)	**53.333** (8.186)	**44.850** (6.226)	3.715	.001
MDI-C sad mood	52.692 (8.430)	**54.417** (8.582)	**47.350** (5.733)	3.046	.011
MDI-C anxiety	**54.308** (9.595)	**54.083** (6.426)	**46.100** (7.725)	**HIP/HE**≠Control : 3.432 **HIP/HO**≠Control : 2.998	.003 .012
MDI-C provocation	51.769 (9.275)	**52.625** (8.963)	**46.100** (7.779)	2.495	.047

*Significant differences appear in bold. The Bonferroni correction was used to adjust the observed significance level.

Table 7: Mean scores (standard deviations) of HIP/HO and HIP/HE groups versus control groups in the anxiety-depression function.

In the anxiety-depression function (**Table 7**), there were no statistically significant differences between the scores of the two HIP groups on the different scales. However, there were significant differences between the HPI/HE group and the control group. The MDI-C total score for the HIP/HE group was significantly higher than for the control group (P*bonf* =.001) and in the sad mood (P*bonf* =.011), provocation (P*bonf* =.047) and anxiety subscales (P*bonf* =.003). The HIP/HO group differed from the control group only on the anxiety scale, where it also showed a higher propensity for anxiety (P*bonf* =.012). There were no significant differences between the groups on the other MDI-C subscales (social introversion and pessimism).

	HIP/HO	HIP/HE	Control	t-test	*Pbonf* *
Imagination	2.846 (1.725)	**3.500 (**2.359)	**1.850 (**1.226)	2.888	.017
Local details	**6.308 (**2.463)	**6.750 (**2.048)	**3.850 (**2.681)	**HIP/HE**≠Control: 4.025 **HIP/HO**≠Control:2.899	<.001 .016
Attention switching	3.538 (1.664)	**5.083 (**2.701)	**3.050 (**1.791)	3.049	.011

*Significant differences appear in bold. The Bonferroni correction was used to adjust the observed significance level; Reminder: the maximum score was 10 points for each of the AQ subscales. The higher the scores, the more they deviated from the norm for children with typical development.

Table 8: Mean scores (standard deviations) of HIP/HO and HIP/HE groups versus control groups in the psycho-cognitive functions (explored through the AQ test subscales).

In the psycho-cognitive functions (explored through the AQ test subscales), the two HIP groups differed from the control group in the information processing function. They obtained higher mean scores in the local details subscale (P*bonf* <.001 for HIP/HE ≠Control; P*bonf* =.016 for HIP/HO ≠ Control), confirming a tendency toward global rather than sequential or analytical processing. In terms of the other functions, the HPI/HE group showed less attention switching and lower imagination potential (respectively, (P*bonf* =.011 and P*bonf* =.017) compared with the control group, as shown in **Table 8**. In the visuoperceptual and visuomotor functions, the comparisons of means did not show any statistically significant differences between the groups (p>.05).

3.3 Comparative analysis of the performances of the four groups, HIP/HO, HIP/HE, AS/HIP and control group

Group characteristics: One sample of 13 HIP/HO children (mean age = 11.8 ± 1.5 years; 6 boys and 7 girls) with mean FSIQ = 141.30 (SD=6.81). One sample of 24 HIP/HE children (mean age = 10.10 ± 2.5 years; 14 boys and 10 girls) with average IQ = 139.41 (SD=6.01). One sample of 5 AS/HIP children (mean age = 11.10 ± 3 years; 5 boys) with average IQ = 137.60 (SD=5.32). One control group sample of 20 children as previously described.

	AS/HIP	HIP/HE	HIP/HO	Control	F(3.58)	*p* value	η^2
AQ total	**35.200** (9.471)	**23.875** (8.926)	**18.308** (7.729)	**11.900** (5.730)	15.663	<.001	.44
Communication	**7.000** (2.915)	**4.083** (2.501)	**2.308** (1.974)	**1.850** (1.785)	9.335	<.001	.32
EQ total	**17.400** (3.209)	**31.375** (14.018)	**38.462** (10.898)	**40.050** (8.846)	6.510	<.001	.25
Social competence	**9.000** (1.732)	**4.458** (2.718)	**3.231** (2.088)	**1.300** (1.418)	19.221	<.001	.49

Table 9: Mean scores (standard deviations) of HIP/HO, HIP/HE and AS/HIP groups versus control group in the social cognition function.

First, it can be seen (**Table 9**) that the mean scores obtained by the AS/HIP and control groups in the AQ test correspond to the French norms established by Sonié et al. [45] and confirm the Asperger's diagnosis for those in the AS/HIP group.

The mean AQ test score significantly differentiated the AS/HIP group from the other three groups (HIP/HE-AS/HIP: t=2.952, P*bonf* =.027, HIP/HO-AS/HIP: t= 4.114, P*bonf* <.001; control-AS/HIP: t=5.972, P*bonf* <.001).

The mean EQ test score also significantly differentiated the AS/HIP group from the other three groups (HIP/HE-AS/HIP: t =-4.366, P*bonf* <.001, HIP/HO-AS/HIP: t =-6.294, P*bonf* <.001; control-AS/HIP: t=9.268, P*bonf* <.001).

The results confirmed that the mean AQ test scores of the AS/HIP children were significantly higher than those of the other groups and that their mean EQ test scores were significantly lower. Across all groups, there was a significant negative correlation between the AQ test scores and the EQ test scores (Pearson's r = - 0.703, p<.001). The scores obtained on the social competence and communication subscales show the considerable difficulties children with Asperger's have in these areas. This group differed very clearly from the other three groups. In terms of social competence: AS/HIP-HIP/HE: t=3.770, P*bonf* =.002, AS/HIP-HIP/HO: t =4.473, P*bonf* <.001; AS/HIP-control: t=9.200, P*bonf* <.001. In terms of communication: AS/HIP-HIP/HE: t =2.676, P*bonf* =.046, AS/HIP-HIP/HO: t= 3.716, P*bonf* =.002; AS/HIP-control: t=4.645, P*bonf* <.001. In the anxiety-depression function, the statistical comparison results did not reveal significant differences between the clinical groups (AS/HIP and HIP) for either the MDI-C total score or the subscales (anxiety, sad mood, social introversion, provocation, pessimism).

	AS/HIP	HIP/HE	HIP/HO	Control	F (3.58)	*p* value
Visuoperceptual functions	99.200 (20.885)	109.917 (12.944)	108.846 (18.832)	103.400 (7.728)	1.420	.246
Visuomotor functions	95.800 (20.080)	105.542 (13.657)	114.692 (17.839)	101.850 (4.082)	2.532	.100

Table 10: Mean scores (standard deviations) of HIP/HO, HIP/HE and AS/HIP groups versus control group in the visuoperceptual and visuomotor functions.

In the visuoperceptual and visuomotor functions (**Table 10**), the mean scores of the AS/HIP group were systematically lower than those of the other three groups in the domains assessed, however these differences were not statistically significant. It is likely that the small sample size contributes to explaining this finding.

3.4 Search for clinical markers differentiating Asperger's syndrome with HIP from HIP without ASD

In order to identify markers to facilitate the differential diagnosis of Asperger's and HIP without ASD, we looked, as a second step in this analysis, for potential subjects in the HIP groups with AQ scores typically found in children at risk of ASD. In Sonié et al.'s [44] study, 88.8% of the participants with autism (AS/High-Functioning Autism) scored above a critical minimum of 26 compared with 5.9% of the control group, and in Baron-Cohen et al.'s [42] study, approximately 90% of the adolescents with AS/High-Functioning Autism scored 30+ versus 0% in the control group.

Consequently, we undertook to identify all those in our HIP groups who had obtained a score of 30 points or more on the AQ test (this score did not apply to any of the children in the control group) because this threshold could potentially be indicative of undiagnosed Asperger's for some of these children. The resulting subgroup, which comprised seven children from the HIP/HE group and one child from the HIP/HO group, was then compared with the AS/HIP group across the variables that had so far proved the most significant.

3.5 Comparative analysis of the performances of the HIP (AQ≥30), HIP (AQ<30) and AS/HIP groups

As shown in **Table 11**, these three samples were characterized by an equivalent cognitive level (FSIQ, p>.05), however the HIP (AQ<30) group had a very significantly lower AQ test score than the other two groups: HIP (AQ<30) and AS/HIP: t=5.696, P*bonf* <.001; HIP (AQ<30) and HIP (AQ≥30): t=-6.774, P*bonf* <.001).

Groups	Number	Mean age / SD	FSIQ /SD*	Total AQ /SD**
HIP (AQ≥30)	8	11 ans et 7 mois/ 2 ; 5	143,25 /4,89	34,87/ 3,79
AS/HIP	5	11 ans et 10 mois/ 3 ans	137,60 /5,32	35,2/ 9,47
HIP (AQ<30)	29	11 ans /2 ; 1	139,20/6,40	18,34/5,96

*F (2,39) =1,768, p=.184 (ns)

**F (2,39) =33,347, p <.001

Table 11: Group characteristics.

The mean AQ scores obtained by the AS/HIP and HIP (AQ≥30) groups correspond to the French norms established by Sonié et al. [44] for children at risk of ASD (35.06; SD=7.46).

	HIP (AQ<30)	HIP (AQ≥30)	AS/HIP	*F (2.39)*	*p* value	η^2
EQ total	38.448 (11.067)	17.250 (4.166)	17.400 (3.209)	21.779	<.001	.52
Communication	2.552 (1.660)	6.750 (2.053)	7.000 (2.915)	22.974	<.001	.54
Social competence	3.172 (1.983)	7.125 (1.959)	9.000 (1.732)	27.074	<.001	.58

Table 12: Mean scores (standard deviations) of HIP (AQ<30), HIP AQ ≥30 and AS/HIP groups in the social cognition function.

In the social cognition function (**Table 12**), and more specifically in the EQ test and the communication and social competence subscales in the AQ test, there was a systematic equivalence of mean scores between the AS/HIP and HIP (AQ≥30) groups (p>.05) and significant differences both between the AS/HIP and HIP (AQ<30) groups and between the HIP (AQ≥30) and HIP (AQ<30) groups:

EQ test: HIP (AQ<30) and AS/HIP: t=-4.529, P*bonf* <.001; HIP (AQ<30) and HIP (AQ≥30): t=5.531, P*bonf* <.001; communication: HIP (AQ≥30) and AS/HIP: t=4.837, P*bonf* <.001; HIP (AQ<30) and HIP (AQ≥30): t=-5.535, P*bonf* <.001; social competence: HIP (AQ<30) and AS/HIP: t=6.157, P*bonf* <.001; HIP (AQ<30) and HIP (AQ≥30): t=-5.063, P*bonf* <.001.

	HIP (AQ<30)	HIP (AQ≥30)	AS/HIP	*F (2.39)*	*p* value	η^2
Imagination	**2.586** (1.680)	**5.750** (1.909)	**5.000** (2.550)	11.345	< .001	.36
Attention switching	**3.586** (1.743)	**8.000** (1.414)	**8.000** (2.828)	26.023	< .001	.57

Table 13: Mean scores (standard deviations) of HIP (AQ<30), HIP (AQ≥30) and AS/HIP groups in the "imagination" and "attention switching" scales.

In the psycho-cognitive functions (explored through the AQ test subscales), and more specifically in the imagination and attention switching subscales, (**Table 13**), there was a systematic equivalence of mean scores between the AS/HIP and HIP (AQ≥30) groups (p>.05) and significant differences between the HIP (AQ≥30) and HIP (AQ<30) groups: "Imagination", HIP (AQ<30) and HIP (AQ≥30): t = -4.330, P*bonf* <.001; "Attention switching": HIP (AQ<30) and HIP (AQ≥30): t = -6.030, P*bonf* <.001.

	HIP (AQ<30)	HIP (AQ≥30)	AS/HIP	*F (2.39)*	*p* value
MDI-C total	52.586 (8.266)	53.000 (8.018)	51.400 (10.922)	0.057	0.945
MDI-C anxiety	54.034 (8.296)	54.625 (4.241)	53.200 (13.312)	0.044	0.957
MDI-C social introversion	53.103 (10.352)	50.250 (9.528)	58.400 (8.112)	1.026	0.368

Table 14: Mean scores (standard deviations) of HIP (AQ<30), HIP (AQ≥30) and AS/HIP groups in the anxiety-depression function.

In the anxiety-depression function (**Table 14**), the statistical comparison results showed that the AQ test score did not influence the mean scores obtained by the groups. Each of the ANOVA results was non-significant (p>.05). With the exception of the social introversion scale for the AS/HIP group (m=58.40), all the mean scores were below 56 (the clinical threshold for this scale). A standardized score of between 56 and 65 indicated a mild to moderate disorder in the function in question, while a score of between 66 and 75 indicated a moderate to severe disorder, and a score above 75 indicated severe symptomatology. A frequency analysis was carried out to identify the number of participants in each group with scores ≥ 56 in this domain. The results for the MDI-C social introversion scale showed that 80% (4/5) of the AS/HIP group, 31% (9/29) of the HIP/AQ<30 group and 12.5% (1/8) of the HIP/AQ≥30 group obtained scores ≥56. While more AS/HIP than HIP participants scored ≥56 on the social introversion scale, the numbers were too small to reveal any significant differences between the groups (χ^2=21.712,

p=.477, Yates correction). The intergroup comparative analyses showed no significant differences between the groups in the visuoperceptual (F (2.39) =1.428, p=.252) or the visuomotor (F (2.39) =2.282, p=.116) functions.

4. Discussion

Our initial objectives were to conduct a series of comparative studies to identify the clinical functional features that may differentiate, on the one hand, children with HIP and children of the same chronological age with typical development and, on the other, children with HIP and a homogeneous FSIQ profile (less than 23 points difference between the highest and lowest index scores) and children with HIP and a highly heterogeneous FSIQ profile (more than 23 points difference between the highest and lowest index scores), in terms of social cognition and anxiety-depression functions and the visuomotor and visuoperceptual domains. A secondary objective was, through the introduction of a sample of children with HIP and an Asperger's syndrome, to identify possible clinical semiology that may facilitate the differential diagnosis of HIP without ASD and Asperger's with HIP.

Our results revealed, first of all, significantly lower social competence (communication, empathy, social skills) in the children with HIP compared to their peers of the same age with typical development (respectively, p=.007, p=.041, p<.001). However, they performed significantly better than the children with typical development in the visuoperceptual (p=.046) and visuomotor tasks (p=.015). Their high cognitive level favorably influenced their performance in tasks that required good attentional and perceptual skills (i.e. when they were required to distinguish simple and complex figures) and good fine motor skills (i.e. when they were required to reproduce simple and complex geometric figures as accurately as possible). In terms of information processing modes, the responses from the children with HIP relating to the psycho-cognitive functions (explored through the AQ test subscales) suggest that they had a higher tendency to grasp and process information globally than those in the control group (p=.001) and a good capacity for synthesis as opposed to processing information in an analytical or sequential manner. Their responses also suggest less attention switching (p=.021). It is important to note, however, that this was an analysis of parents' responses to a questionnaire and not of any tasks performed by the children to explore their functional approaches.

In the MDI-C scale, the children with HIP scored significantly higher than the control group on the anxiety, sad mood and total depression scales (p<.001). These results were consistent with the intrinsic affective fragility that has been noted among this population, which can result in a personality that is more anxious than that of the general population. They also confirmed the findings of many recent studies conducted on this population [15, 17, 18], which have suggested often marked affective, emotional and social difficulties in these children. However, as we pointed out in our introduction, these findings are far from unanimous among researchers. Some have proposed that this association between a very high IQ and affective, social and behavioral difficulties occurs more specifically in children with HIP and a very heterogeneous IQ profile.

We tested this last proposition in a second step in our analysis by splitting the HIP group into two subgroups, one containing the children with a homogeneous IQ profile and the other those with a very heterogeneous IQ profile, in order to check whether the latter would be more likely than the former to manifest difficulties, particularly in the socio-emotional functions.

The comparative analyses we conducted primarily on the psychometric profiles of our HIP groups revealed some significant differences in index scores. The children with HIP and a homogeneous profile showed good mnemonic skills and an information processing speed that was much higher than the mean. The children with HIP and a heterogeneous profile obtained much lower scores in these functions than the children with HIP and a homogeneous profile ($p<.001$ and $p=.024$ respectively). These characteristics of the HPI/HO children show effective, dynamic cognitive functioning for problem solving and environmental response. These associated functional characteristics are correlated with a high intellectual level [47].

Some studies have shown that HIP is an asset that allows for optimal cognitive functioning to draw on the knowledge base available [1]. However, paradoxically, outside academia, children with HIP are reported as having difficulties with tasks that assess information processing speed, memory and attention. We have observed that children with HIP and a very heterogeneous profile are more represented in the school populations and, notably, more represented among the children who present for clinical consultations. This observation may help to explain an excessive generalization of the findings on modes of functioning that are specific to children with HIP and a heterogeneous profile to the entire HIP population, which leads to erroneous representations of their cognitive functioning and even to inappropriate practices in the psycho-cognitive assessment of these children.

In our study, the children with HIP and a heterogeneous profile obtained “average” scores in information processing speed and working memory, that is scores that sometimes deviated by more than 15 points from the other index scores. These discrepancies between the indices may explain the perceived “difficulties” sometimes reported by psychologists, which they tend to generalize to the entire HIP population. Ultimately, they seem to apply only to children with HIP and a heterogeneous profile.

In terms of the social cognition function, the two HIP groups did not significantly differ from one another. Nevertheless, we found that the scores of the children with HIP and a homogeneous profile were always closer to those of the control group than those of the HIP group with a heterogeneous profile. The latter group had a higher mean AQ score ($P_{bonf} <.001$) and presented significantly more difficulties than the control group in the communication ($P_{bonf} =.004$), empathy ($P_{bonf} =.044$) and social skills ($P_{bonf} <.001$) functions. Similar results were observed for the anxiety-depression function. There were no statistically significant differences between the two HIP groups. Nevertheless, the children with HIP and a heterogeneous profile clearly differed from the control group in that they revealed significantly more difficulties in the MDI-C total scale ($P_{bonf} =.001$) as well as in several of its

subscales by presenting specific symptoms (sad mood, provocation), while the HIP group with a homogeneous profile differed from the control group only on the anxiety scale (P*bonf* =.012). Overall, these results highlight a more anxious personality in children with HIP, regardless of their psychometric profile, compared with children with typical development, thus confirming the results of some of the studies [3, 17, 18].

Moreover, it appears that difficulties in the affective-communication functions (AQ, EQ, communication skills) and social competence were more marked in the children with HIP and a heterogeneous profile than in those with HIP and a homogeneous profile, whose scores were similar to those of the control group. This finding consequently confirms one of our hypotheses, which proposed that children with HIP and a very heterogeneous psychometric profile have more marked difficulties in emotional sensitivity and in relating to others. However, our findings do not confirm the hypothesis that children with HIP and a heterogeneous profile experience more marked difficulty in the visuoperceptual and visuomotor functions. In the second step of our study, we introduced a group of children diagnosed with HIP and Asperger's syndrome in order to carry out a pilot comparative study, notably using the HIP groups, to try to shed light on a semiology that might differentiate them.

This pilot study showed first of all the influence of Asperger's semiology on performances in the communication, empathy and interaction functions. The mean scores of this group of children with HIP and Asperger's showed that they always had significantly more marked difficulties in these domains than the two HIP groups (P*bonf* <.001). However, in the anxiety-depression domain, as assessed by the MDI-C, there were no significant differences between this group and the two HIP groups.

Finally, based on the work of Baron-Cohen et al. [42], which proposed an indicative clinical threshold in the AQ test for a substantial risk of ASD, we extracted from our two HIP groups those children obtaining a score ≥ 30 in the AQ test. Our comparative analyses revealed that these children's scores were similar to those of the children diagnosed with Asperger's in the communication, empathy, social competence functions, imagination and attention switching. These results were significantly different from the scores of the children with HIP and an AQ score <30 (p<.001).

5. Conclusions

The limitation of our study lies in the smallness of our sample of children diagnosed with Asperger's syndrome. Results should be interpreted with caution and confirmed with larger samples. However, the trends revealed through our comparisons of the groups' scores are robust. It appears that some children in our HIP groups, especially those with a heterogeneous profile and considerable social and emotional difficulties, are at high risk of being children with Asperger's syndrome but they were undiagnosed and non-suspected of ASD when we included them in our study. Their possible Asperger's syndrome will remain likely undiagnosed.

This finding, namely that a child with HIP and a very heterogeneous psycho-cognitive profile (with a difference of more than 23 points between the lowest and the highest index scores) that is associated with considerable difficulties in social interaction, empathy and communication, suggests that the completion of an AQ questionnaire should be mandatory. In the case of scores above a certain AQ threshold, a complete child and adolescent multidisciplinary assessment should be indicated to test the hypothesis of ASD. This approach would make it possible to establish a differential diagnosis between HIP without ASD and Asperger's with HIP and to devise appropriate support. As some authors have suggested [8, 48, 49], clinicians should be advised to seek confirmation of assumptions of potential vulnerability that are based, for example, on a very marked heterogeneity in the psychometric profile through other sources of information, such as academic performance, social skills and other multidimensional tests results. The AQ test, which is a screening rather than a diagnostic tool for autism [50, 51], is freely available and easy to administer. We think it could therefore be valuable in terms of improving the detection of undiagnosed cases, which should then be referred for a full diagnostic assessment. The current study did not allow access all brain functions, but prospective clinical investigations should add more assessments in the neuropsychomotor field to complete behavioral tests.

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Conflict of Interest

The authors declare no competing and financial interests.

Author Contributions

LVD and PP conceived the study, collected the data and conducted the analyses. Both authors wrote the manuscript.

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