Psychiatry Research 281 (2019) 112576

Contents lists available at ScienceDirect

Psychiatry Research

journal homepage: www.elsevier.com/locate/psychres

Measuring subthreshold autistic traits in the general population: Psychometric properties of the *Adult Autism Subthreshold Spectrum* (AdAS Spectrum) scale

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ARTICLE INFO

Keywords:
Autism spectrum disorder
Subthreshold autistic traits
AdAS Spectrum scale
Dimensionality
Reliability
Validity

ABSTRACT

The *Adult Autism Subthreshold Spectrum* (AdAS Spectrum) has been developed to assess the wide spectrum of autistic-like clinical and non-clinical features in adults. Nevertheless, its psychometric properties have been analyzed only with clinical individuals so far. This study was aimed at investigating the dimensionality, reliability and validity of the AdAS Spectrum on a non-clinical sample. Participants were 395 Spanish undergraduate students (60% males; mean age of 21.1 years, SD = 2.6), who completed the AdAS Spectrum, the *Autism-Spectrum Quotient* (AQ), and the *Empathy Quotient* (EQ). A confirmatory factor analysis supported the seven-factor structure of the questionnaire. Internal consistency was excellent for the total score and acceptable for five factors. Test-retest reliability over a 4-week period was good. Higher AdAS Spectrum scores significantly correlated with higher AQ and lower EQ scores, supporting the validity of the scale. Moreover, participants studying Science/Technology programs did significantly differ from students following Social/Humanities degree courses on all the AdAS Spectrum scores. Overall, findings support the psychometric properties of the AdAS in a non-clinical sample. Future research is needed to further examine the factorial structure and the internal consistency of the scale in larger samples of general population.

1. Introduction

Autism spectrum disorder (ASD) is characterized by a deficit in social communication and interaction, and by a pattern of narrow interests and repetitive behavior (Billeci et al., 2016; Carpita et al., 2018). To overcome a rigid categorical system (American Psychiatric Association, APA, 2013; Dell'Osso et al., 2016a), the *Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition* (DSM-5) (APA, 2013) included Autistic disorder, Asperger's disorder and Pervasive Developmental disorder not otherwise specified, as reported in the *DSM – Fourth Edition – Text Revised* (DSM-IV-TR (APA, 2000), under the wide ASD label. However, the "spectrum" concept of the DSM still features only full-blown manifestations, while a growing body of literature highlights the relevance of considering also *subthreshold autistic traits* (SATs) from a psychopathological point of view (Dell'Osso et al., 2015, 2016a, 2016b).

Indeed, ASD would seem to represent extreme values on multiple functional domains that may show a continuous distribution in the general population (e.g., Baron-Cohen et al., 2001; Constantino and Todd, 2003; Dell'Osso et al., 2016a, 2016b). Converging evidence suggests that SATs are common and show substantial variation in general population samples (e.g., Hoekstra et al., 2007; Ronald and Hoekstra, 2011; Skuse et al., 2005). Supporting the proposal of the so-called "Broad Autism Phenotype" (e.g., Billeci et al., 2016; Bishop et al., 2004; Constantino et al., 2006), previous research showed that first-degree relatives of ASD patients report elevated SATs, and the endorsement of SATs was found to be high in children from the general population whose parents also reported high SATs (Constantino and

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https://doi.org/10.1016/j.psychres.2019.112576
Received 10 April 2019; Received in revised form 22 September 2019; Accepted 22 September 2019
Available online 23 September 2019
0165-1781/

Todd, 2005). There is also evidence to support that SATs in adults from the general population reflect similar, though less severe, social-cognitive and emotional features compared to those observed in ASD (Gökçen et al., 2014). Additionally, empirical data suggest that SATs are associated with psychosocial impairment in adults from the general population. For example, high levels of SATs in young adults are related to increased loneliness and to a lower number and duration of friendships (Jobe and White, 2007), higher anxiety, depression and difficulties in social and personal adjustment (Kanne et al., 2009), as well as in executive control abilities (Christ et al., 2010). In the same line, Asano et al. (2014) showed that SATs were associated with an increased risk for postpartum depression in a sample of pregnant women. Furthermore, SATs are particularly elevated in some high-risk groups such as parents of children with epilepsy (Carmassi et al., 2018), and patients with borderline personality (Dell'Osso et al., 2018a) or eating disorders (Dell'Osso et al., 2018b; Tonacci et al., 2019).

In consideration of these and other related findings, the *Subthreshold Autism Spectrum Model* has been recently proposed (Dell'Osso et al., 2016a, 2019). From this perspective, the conceptualization of ASD as a "spectrum" should refer not only to the dimensional nature of the core features of ASD within the clinical population, as conceptualized by the DSM-5, but also to the continuity between the clinical and the general population (Dell'Osso et al., 2016a, 2019). In addition, the term "spectrum" should encompass not only the core ASD features but also mild/atypical symptoms, gender-specific features, behavioural manifestations and personality traits associated with ASD (Dell'Osso et al., 2015, 2016a). Furthermore, SATs are proposed as transnosographic conditions that may impact on the clinical presentation of other mental disorders and that may increase the vulnerability to other mental disorders and to suicidability (Dell'Osso et al., 2016a). Indeed, accumulated evidence shows high rates of comorbidity between ASD/SATs and a range of mental disorders, including stress-related, eating, obsessive-compulsive and mood disorders, as well as suicidal ideation and behavior (Dell'Osso et al., 2019; Mito et al., 2014; Takara and Kondo, 2014).

On the basis of this model, Dell'Osso et al. (2017) recently developed the *Adult Autism Subthreshold (AdAS) Spectrum*, a questionnaire aimed at assessing the wide spectrum of autistic-like clinical and non-clinical features in adults with average intelligence and without language impairment (see Appendix A). To date, available instruments addressing ASD or even SATs, such as the *Autism-Spectrum Quotient* (AQ; Baron-Cohen et al., 2001), have mainly been based on a qualitative approach and largely focused on the core ASD features (Baron-Cohen et al., 2001; Dell'Osso et al., 2019). Additionally, they do not take into account the changes in the remodeling of ASD criteria introduced by the DSM-5, in which deficits in communication are considered strictly related to social deficits (DSM-5 merged the Social and Communication domains of DSM-IV into one single domain), and hyper-hypo reactivity to sensory inputs has been included as an ASD symptom.

Instead, the AdAS Spectrum has been developed based on the DSM-5 remodeling of ASD symptoms. It is not intended to be a diagnostic instrument as it is aimed at assessing the presence/absence of SATs in the lifetime of an individual, even if he/she does not fulfill the ASD diagnostic criteria. This issue is linked to the dimensional and wider approach of the instrument, which allows to assess not only the core ASD features but also a broader area of clinical and non-clinical manifestations, such as atypical traits, behavioural manifestations and temperamental factors, in a quantitative way. In particular, specific attention has been provided in featuring also some female-specific manifestations that are often not properly measured by available instruments, which seem to feature an over-reliance on male symptoms (Baron-Cohen et al., 2001; Dell'Osso et al., 2017). Furthermore, the AdAS Spectrum includes a specific domain to assess hyper- hyporeactivity to sensory inputs which, despite receiving considerable relevance as an ASD symptom in the DSM-5, is only poorly explored by the other available questionnaires (Dell'Osso et al., 2017).

Given its broad and dimensional approach, the AdAS Spectrum is articulated into seven theoretically derived domains. The *Child/Adolescence* domain focuses on ASD symptoms occurring during early developmental phases (e.g., being very quiet or unable to speak at all, avoiding eating or playing with other children at school). Two domains cover *Non-Verbal Communication* features (e.g., difficulty in looking others straight in the eye, feelings of discomfort about hugging, kissing or holding someone by the hand) and *Verbal Communication* features (e.g., tendency to speak with a very low voice or in a strange or monotonous way, difficulties in intervening in or ending a conversation, habit of inadequately butting into a conversation). One additional dimension assesses *Low Empathy* (e.g., difficulties in understanding and interpreting the facial expressions, intentions or thoughts of others). The remaining domains explore *Inflexibility and Adherence to Routine* (e.g., difficulties in understanding the nuances of things or in changing daily habits or methods of work, tendency to follow precise procedures or patterns), *Restricted Interests and Rumination* (e.g., talking only about a few preferred topics, being fascinated by numbers and systematic information, incapacity to be concise), and *Hyper- and Hyporeactivity to Sensory Input* (e.g., the tendency to over- or under-react to noises, textures, pain or temperature).

Dell'Osso et al. (2017) explored some psychometric properties of the AdAS Spectrum in a sample of patients with feeding and eating disorders (FED), of mental health patients endorsing at least one criterion symptom for ASD (ASDc), and of individuals without current or lifetime mental disorders (CTL). Internal consistency was excellent for the AdAS Spectrum total score (Kuder-Richardson's coefficient = 0.96). Five domains (i.e., *Child/Adolescence, Verbal* and *Non-Verbal Communication, Inflexibility and Adherence to Routine*, and *Restricted Interests*) proved good internal consistency (coefficients ≥ 0.80). Reliability coefficients were lower –yet acceptable- for *Low Empathy* (0.76) and *Hyper- and Hyporeactivity* (0.79) domains. Total and domain scores showed moderate to strong positive correlations (> 0.50) with one another. Test-retest reliability was excellent (ICC = 0.98) over a two-week interval. AdAS Spectrum scores positively correlated with other well-established measures of autism characteristics, such as the AQ. Furthermore, the AdAS Spectrum scores demonstrated to differentiate among FED, ASDc and CTL subjects, and to detect a different expression of sensory reactivity by gender group, as females showed higher scores on the *Hyper- and Hyporeactivity to Sensory Inputs* subscale compared to males across the three groups of participants. Given its good psychometric properties, the instrument has been employed in different clinical and non-clinical samples, providing new insights about the relationship of the autism spectrum with different psychopathological dimensions (Dell'Osso et al., 2018a, 2018b, 2018c, 2019).

Taken together, the above findings suggest that the AdAS Spectrum is a promising tool for testing new dimensional conceptualizations of ASD that extend SATs to the general population (Gökçen et al., 2014). However, although the AdAS Spectrum was specifically developed as a non-diagnostic tool for assessing lifetime SATs in non-clinical adults, evidence about its psychometric properties is limited to one study with a clinical and nonclinical sample (Dell'Osso et al., 2017). Hence, the purpose of the present study was to evaluate the psychometric properties of the AdAS Spectrum in a non-clinical sample. In particular, the aim of this work was twofold. Firstly, as the seven domains of the AdAS Spectrum have been only theoretically described (Dell'Osso et al., 2017), we aimed to empirically verify the hypothesized seven-factor model as well as to assess the reliability and validity of the scale. We expected to obtain good internal consistency and temporal stability, in line with the original study (Dell'Osso et al., 2017). As for validity, we examined the relations of the AdAS Spectrum scores with two conceptually related and well-established measures in the field: The AQ (Baron-Cohen et al., 2001) and the *Empathy Quotient* (EQ; Baron-Cohen and Wheelwright, 2004). We predicted that the AdAS scores would positively correlate with the AQ total score (Dell'Osso et al.,

2017), and negatively with the EQ total score. Indeed, individuals with ASD show difficulties in identifying others' thoughts and in understanding non-literal expressions such as metaphors, sarcasm and lies (e.g. Kaland et al., 2002), and ASD traits have been shown to be highly and negatively correlated with empathizing ability in adults with a diagnosis of ASD (e.g., Russ et al., 2018). Concerning gender differences, in line with the validation study (Dell'Osso et al., 2017), we hypothesized to obtain a substantial homogeneity across genders in the AdAS Spectrum total and subscale scores. Furthermore, as previous research suggested that science students show a more systemizing-driven cognitive style when compared to humanities students, whereas the latter show a more empathizing-driven style (e.g., Baron-Cohen et al., 2001; Focquaert et al., 2017), we hypothesized that participants engaging in Science/Technology programs would score higher on the AdAS Spectrum than those engaged in Social/Humanities studies.

2. Method

2.1. Participants

Participants were 395 undergraduate students (60% males) from the University of Malaga (Spain). Their mean age was 21.1 years (SD = 2.6; range = 18 - 30). Fifty-five percent of participants were pursuing Science/Technology degrees (Engineering, Medicine, Computer Science, Maths or Chemistry), and the remaining 45% were pursuing Humanities/Social programs (Psychology, Criminology, Educational Science, Economic, Journalism, Law, Linguistics, Marketing, Social Work, Translation and Interpreting).

2.2. Measures

The research protocol included a form for gathering socio-demographic data. Participants then answered the AdAS Spectrum, the AQ, and the EQ.

The AdAS Spectrum consists of 160 items, each reflecting a specific SAT, with dichotomous response scale (yes/no). The pool of items is organized into the following seven domains: *Child/Adolescence* (C/A) consists of 21 items (e.g., "At school did you ever avoid eating or playing or doing gymnastics with other children?"), *Verbal Communication* (VC) with 18 items (e.g., "Do you tend to not speak much and/or use very short sentences?"), *Non-Verbal Communication* (NVC) with 28 items (e.g., "Do you feel uncomfortable if someone looks at you insistently?"), *Low Empathy* (LE) with 12 items (e.g., "Is it difficult for you to identify with someone else?"), *Inflexibility and Adherence to Routine* (IAR) with 42 items (e.g., "Do you ever feel the need to touch repeatedly an object or a part of your body without any apparent reason?"), *Restricted Interests and Rumination* (RIR) with 21 items (e.g., "Are you particularly good at picking up detail (e.g., parts of objects, parts of the body, etc.?"), and *Hyper- and Hyporeactivity to Sensory Input* (HIS) with 17 items (e.g., "Have you ever perceived buzzing or low noises to be amplified or even unbearable?"). Domain and total scores are obtained by counting the number of positive answers, with higher scores indicating higher SATs endorsement.

The original AdAS Spectrum was developed in Italian by Dell'Osso et al. (2017). A standard "forward-backward" translation method was used to assess the linguistic equivalence of the AdAS Spectrum. First, a Spanish native speaker translated the Italian version of the AdAS Spectrum into Spanish. The resulting draft was then translated back into Italian by an Italian native speaker who is also fluent in Spanish. Discrepancies and inconsistencies between both versions were then checked and discussed in order to ascertain as far as possible the correspondence of the Spanish version to the original scale. The final version was then assessed by two mental health experts who agreed on the accuracy of the translation and on the good face validity with the questionnaire.

The Spanish translations of the AQ and EQ were used (https://www.autismresearchcentre.com/arc_tests). The AQ (Baron-Cohen et al., 2001) is a 50-item self-report questionnaire designed to assess autistic traits in adults with normal intelligence. Each item is rated on a 4-point scale ("strongly agree", "slightly agree", "slightly disagree", "strongly disagree"). Responses to each item are coded using a binary system, where an endorsement of the autistic trait (either "slightly" or "strongly") is scored as $a + 1$, while the opposite response is scored as a 0. Hence, the AQ total score ranges from 0 to 50, with higher scores indicating higher AT. The AQ proved to have good internal consistency and temporal stability (Baron-Cohen et al., 2001; Jobe and White, 2007), as well as adequate discriminant validity (Baron-Cohen et al., 2001). Previous research also indicated that the AQ is a valid and useful tool for screening autism traits in nonclinical samples (Murray et al., 2016; Ruzich et al., 2015).

The EQ (Baron-Cohen and Wheelwright, 2004) is a 60-item self-report questionnaire developed to measure empathy in adult samples with normal intelligence. The questionnaire includes 40 items assessing empathy and 20 filler items. Items are rated on a 4-point scale ("strongly agree", "slightly agree", "slightly disagree", "strongly disagree"). Items measuring empathy score two points if the respondent endorses "strongly" the emphatic behavior, and one point if the respondent records the empathic behavior "slightly". Hence, higher EQ scores indicate higher empathy. The EQ demonstrated good internal consistency, temporal stability and convergent and discriminant validity to differentiate between clinical and normal samples (Baron-Cohen and Wheelwright, 2004). Moreover, the scale shows good construct and concurrent validity (Allison et al., 2011; Lawrence et al., 2004).

2.3. Procedure

The study was conducted in accordance with the Declaration of Helsinki. The Local Ethics Committee approved the recruitment and assessment procedures.

Participants were recruited among students attending courses at the University of Malaga between October 2017 and June 2018. After providing informed consent, most students were asked to complete the questionnaire pack in class. Participation was voluntary, anonymous and had no effect on the students' academic standing. In order to evaluate the test-retest reliability of the scale, a subsample of 49 participants completed the AdAS Spectrum again after a four-week interval. Most participants completing the retest were females (73.5%) from Social/Humanities degree courses (89.8%). Mean age was 22.40 (SD = 1.68, range = 20 - 27).

2.4. Statistical analyses

As a preliminary step, cases with high levels of missing data in the AdAS Spectrum (> 10% in the same domain) were removed. Missing data were replaced with the domain mean in the remaining cases. Item responses were preliminarily tested for asymmetry and kurtosis. Missing values in both the AQ and the EQ were replaced with the item mean.

In line with previous work on multidimensional scales (e.g., Kellison et al., 2010), a confirmatory factor analysis (CFA) with a "parceling" approach was applied on the 160 items of the AdAS Spectrum in order to test the hypothesized seven-factor structure. We adopted this approach to reduce the number of observed variables, as fit statistics are affected by the number of items (Kenny and McCoach, 2003), and scales with large numbers of items generally have poor fit (Cook et al., 2009; Floyd and Widaman, 1995). Indeed, as reported by Allison et al. (2015), the unique variances of items in CFAs can be correlated because the items share a specific feature. The more items there are, the more this becomes likely, and even particularly common when many items are constructed from similar domains, as is

the case with the AdAS Spectrum. Moreover, parcels of items are also more reliable and more likely to have linear relations with each other and with the proposed latent factors (Comrey, 1988), especially when there are more than 12 items in a scale (Yang et al., 2010). Among the possible approaches to parceling (Landis et al., 2000), we applied the random parceling. Thus, five parcels per domain were randomly created, hence resulting in a model based on 35 observed variables. The CFA was performed using MPLUS (Muthén and Muthén, 2012). The Weighted Least Squares with Mean and Variance Adjusted (WLSMV) estimator for dichotomous variables was used. The following indices were examined to assess the model fit: The normed chi-square (χ^2/gdl), the Comparative Fit Index (CFI; Bentler, 1990), the Tucker-Lewis Index (TLI; Tuker and Lewis, 1973), and the Root Mean Square Error of Approximation (RMSEA; Steiger and Lind, 1980).

Internal consistency was assessed using Kuder-Richardson coefficients for each AdAS Spectrum domain and for the total score. Pearson's correlation coefficients were calculated to explore the test-retest reliability of the AdAS Spectrum, the relations among the AdAS domains, and the associations of the AdAS scores with the AQ and the EQ total scores. To further address the validity, we first looked at gender differences in AdAS scores by means of independent samples *t*-tests. Then, participants were divided into groups of Science/Technology and Social/Humanities students according to their degree program, and independent sample *t*-tests were performed to explore between-group differences on the AdAS Spectrum.

3. Results

Less than 1% of participants had missing data at the AdAS items. No case showed high levels of missing data in the AdAS Spectrum. Hence, no participant was excluded and missing values were replaced with the domain mean. Less than 1% of missing values was found also in the AQ and EQ items too, and replacement with the item mean was adopted.

3.1. Dimensionality

Table 1 displays item-to-parcel allocation following the random parceling method. For each dimension, five parcels were created by randomly allocating subgroups of items.

The results from the CFA supported the hypothesized seven-factor model for the AdAS Spectrum items. All indices showed a good model fit for this sample ($\chi^2 = 304.62$, $df = 172$, $\chi^2/df = 1.77$, $p < .001$; CFI = 0.95; TLI = 0.98; RMSEA = 0.04). Furthermore, all items showed high loadings on the respective factor, and correlation coefficients among the AdAS Spectrum factors were moderate to strong (from 0.49 to 0.92; $p < .001$) (Fig. 1).

3.2. Reliability

Table 2 shows internal consistency and test-retest coefficients. According to the criteria of the European Federation of Psychologists' Associations (EFPA, Evers et al., 2013), internal consistency was excellent for the total AdAS Spectrum score (KR coefficient = 0.92) and adequate for three domains (i.e., NVC, IAR, and RIR), almost adequate for C/A and HIS, and inadequate for the VC and LE domains.

Test-retest reliability was excellent for the NVC, LE, and IAR domains, good for the other subscales, and adequate for the total score (Evers et al., 2013).

3.3. Validity

With regard to validity, all the AdAS Spectrum subscale scores correlated positively with the total score, with coefficients ranging from moderate to strong, and most of the coefficients for the correlations among the domains were moderate (Table 3).

As expected, the AdAS Spectrum scores significantly and positively correlated with the AQ total score: $r = 0.36$ for C/A; $r = 0.49$ for both VC and IAR; $r = 0.44$ for NVC; $r = 0.46$ for both LE and RIR; $r = 0.29$ for HIS; and $r = 0.57$ for the total score ($p < .001$).

In line with the predictions, a higher total score at the AdAS Spectrum was related to a lower total score at the EQ ($r = -0.37$; $p < .01$). All the subscale scores significantly and negatively correlated with the EQ total score ($r = -0.23$ for C/A; $r = -0.33$ for both VC and NVC; $r = -0.42$ for LE; $r = -0.26$ for IAR; $r = -0.27$ for RIR; $r = -0.16$ for HIS ($p < .01$).

We also looked at gender differences. Females showed higher scores than males on the NVC subscale (Table 4). However, according to Cohen (1988), the effect size was low.

Finally, as hypothesized, participants studying Science/Technology programs showed significantly higher scores on all the AdAS Spectrum domains compared to the participants studying Social/Humanities degrees (Table 5). Most effect sizes were medium, i.e., for the total score and the C/A, VC, RIR, LE, and IAR domains. Effect sizes for the remaining two factors were small.

Table 1
Random parceling for the items of the AdAS Spectrum scale.

AdAS Spectrum domains	Parcels	Items (number in the scale)
Childhood/Adolescence	P1	1, 7, 12, 17
	P2	2, 6, 11, 16
	P3	3, 8, 14, 19
	P4	4, 10, 13, 18
	P5	5, 9, 15, 20, 21
Verbal Communication	P1	22, 25, 33, 37
	P2	23, 31, 32, 39
	P3	24, 27, 35, 38
	P4	26, 30, 34
	P5	28, 29, 36
Non Verbal Communication	P1	40, 42, 47, 58, 61, 65
	P2	41, 48, 52, 57, 60, 67
	P3	43, 46, 51, 59, 63, 66
	P4	44, 50, 54, 55, 62
	P5	45, 49, 53, 56, 64
Low Empathy	P1	68, 74, 78
	P2	69, 73, 79
	P3	70, 76
	P4	71, 75
	P5	72, 77
Inflexibility and Adherence to Routine	P1	80, 87, 92, 97, 101, 105, 111, 115, 122
	P2	81, 88, 90, 95, 102, 108, 110, 117, 120
	P3	82, 86, 91, 96, 104, 106, 113, 118, 121
	P4	83, 89, 93, 98, 103, 107, 112, 116
	P5	84, 85, 94, 99, 100, 109, 114, 119
Restricted Interests and Rumination	P1	124, 131, 135, 138, 143
	P2	123, 128, 133, 140
	P3	125, 129, 134, 139
	P4	126, 132, 137, 141
	P5	127, 130, 136, 142
Hyper- and Hyporeactivity to Sensory Input	P1	145, 146, 155, 156
	P2	144, 147, 154, 160
	P3	148, 151, 157
	P4	149, 152, 158
	P5	150, 153, 159

$n = 395$.

4. Discussion

The AdAS Spectrum is a non-diagnostic tool developed to assess lifetime SATs through a dimensional and wider approach compared to the other available instruments in the field. However, to date, its psychometric adequacy has been investigated solely in a sample of clinical individuals, and its dimensional structure only theoretically

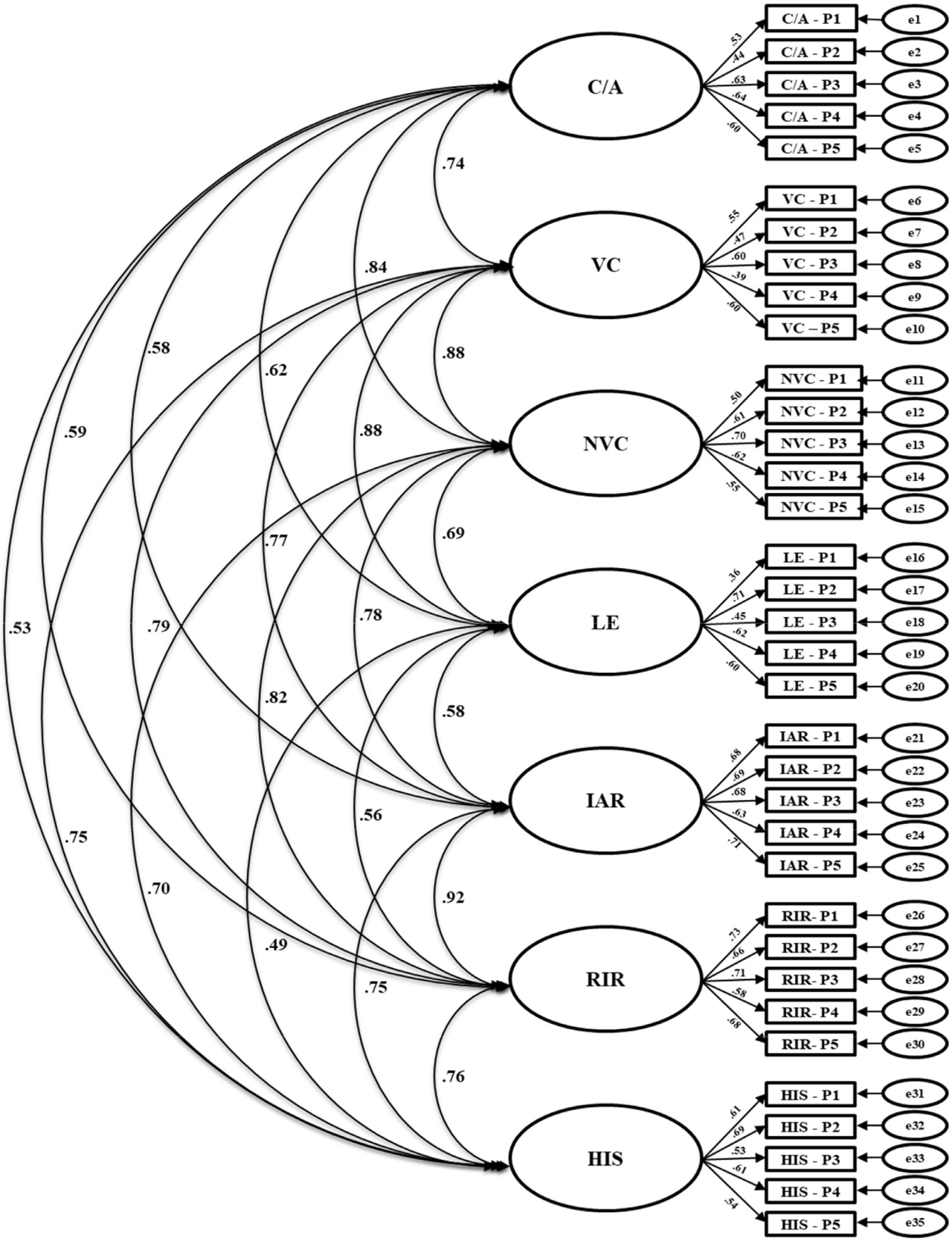

Fig. 1. Path diagram for the Confirmatory Factor Analysis showing standardized regression weights for the AdAS Spectrum items onto the subscales (C/*A = Child/Adolescence*, VC = *Verbal Communication*, NVC = *Non-Verbal Communication*, LE = *Low Empathy*, IAR = *Inflexibility and Adherence to Routine*, RIR = *Restricted Interests and Rumination*, HOS = *Hyper- and Hyporeactivity to Sensory Input*) and correlations between the subscales.
Note: items for each parcel are showed in Table 1; all standardized parameters are significant at 0.001. $n = 395$.

Table 2
Internal consistency (Kuder-Richardson coefficient) and test-retest (Pearson's coefficient) reliability for the AdAS Spectrum domains and for the total score.

AdAS Spectrum scale Domains	Internal consistency Kuder- Richardson [95% CI]	Test-retest *r*
Childhood/Adolescence	.67 [.62 - 0.71]	.79*
Verbal Communication	.57 [.51 - 0.63]	.76*
Non-Verbal Communication	.72 [.68 - 0.76]	.82*
Low Empathy	.54 [.47 - 0.61]	.85*
Inflexibility and Adherence to Routine	.78 [.75 - 0.81]	.81*
Restricted Interests and Rumination	.77 [.73 - 0.80]	.78*
Hyper- and Hyporeactivity to Sensory Input	.66 [.61 - 0.71]	.78*
Total score	.92 [.91 - 0.93]	.67*

Note: 95% CI = 90% confidence interval, *r* = Pearson's correlation coefficient.
* $p < .001$, $n = 395$.

Table 4
Differences across genders in domains and total scores on the AdAS Spectrum scale.

AdAS Spectrum scale Domains	Male ($n = 236$) Mean (SD)	Female ($n = 159$) Mean (SD)	Student's *t* -test *t* (393)	*p*	*d*
Childhood/Adolescence	6.40 (3.31)	5.92 (3.19)	1.43	.155	.15
Verbal Communication	4.78 (2.60)	4.63 (2.72)	.55	.580	.06
Non-Verbal Communication	8.77 (4.33)	7.92 (4.11)	1.94	.054	.06
Low Empathy	3.03 (2.02)	2.71 (1.86)	1.61	.109	.16
Inflexibility and Adherence to Routine	13.44 (5.69)	13.30 (6.05)	.24	.809	.02
Restricted Interests and Rumination	8.38 (3.98)	7.67 (4.06)	1.71	.088	.18
Hyper- and Hyporeactivity to Sensory Input	3.66 (2.62)	3.75 (2.76)	−0.32	.751	.03
Total score	48.46 (18.66)	45.91 (19.27)	1.32	.188	.13

Note: SD = standard deviation, *d* = Cohen's effect size.
$n = 395$.

hypothesized (Dell'Osso et al., 2017). The aim of this study was to examine the psychometric properties of the AdAS Spectrum in a sample from the general population. We aimed at confirming the good reliability and validity of the questionnaire, at verifying the hypothesized seven-factor structure (Dell'Osso et al., 2017), and at investigating its validity more deeply by testing the differences in the AdAS Spectrum on the basis of the kind of academic pathway (Science/Technology or Social/Humanities degrees) taken.

Through a parceling procedure, the current study found support for the seven-factor structure of the AdAS Spectrum, with the predicted factors which resulted to be positively and significantly related to each other. This result provides an essential statistical support to the questionnaire as a tool effectively able to assess the SATs in the general population, as theorized in the *Subthreshold Autism Spectrum Model* (Dell'Osso et al., 2016a, 2019). In particular, the confirmation of a multifactorial structure can lead to delineating an accurate, precise profile: Instead of providing only a unique total score, the multidimensionality of the scale allows to identify which specific domain(s) may require more urgent attention or intervention. Notably, the dimensions correlated between them, meaning that, though allowing to investigate the specific problematic area(s), the constructs examined by the scales relate to one other, in line with the clinical definition of ASD (APA, 2013), and the hypothesized homogeneous internal structure of the AdAS Spectrum (Dell'Osso et al., 2017).

With regard to reliability, internal consistency was excellent for the total scale, while inadequate values were found for the VC and LE domains. Although Dell'Osso et al. (2017) found good internal consistency values for these two subscales, these dimensions showed the lowest KR coefficient values in our study. Since the test-retest period is longer, the results regarding the temporal stability confirm and extend that previously found by Dell'Osso et al. (2017).

As for validity, the correlations of the AdAS Spectrum scores with similar and theoretically related constructs showed that higher scores on the AdAS Spectrum were related to higher AQ scores, in line with the validation study (Dell'Osso et al., 2017), with most of the coefficients of moderate size. It is worth noting that coefficients were not high enough to suggest that the AQ and the AdAS Spectrum measure the same construct. Indeed, as noted above, the AdAS Spectrum was developed for capturing not only the primary ASD features, as the AQ mainly does, but a broader spectrum of lifetime AT-related phenomena (e.g. atypical signs and symptoms of ASD). Moreover, the lower correlation coefficients found for the C/A and the HIS domains can be explained by the fact that the AQ does not address the AT phenomenology as measured by these two AdAS Spectrum domains. Furthermore, higher AdAS Spectrum subscale and total scores significantly correlated with lower EQ scores, confirming previous studies about a negative relationship between autistic traits and empathy (e.g., Kaland et al., 2002; Russ et al., 2018), with the highest correlation coefficient for the relationship with the LE domain. Furthermore, we enlarged evidence about the validity found by Dell'Osso et al. (2017), finding that the AdAS Spectrum subscale and total scores were able to discriminate between students of scientific-technological vs. social-humanistic courses. As far as gender differences are concerned, our results are overall in line with those of Dell'Osso et al. (2017), who found substantial homogeneity across genders on the AdAS Spectrum scores.

Some potential limitations of this study have to be noted. Firstly, participants in this study were undergraduate students, not necessarily representative of the general population, and they were not assessed for current or lifetime mental disorders. Then, the parceling method employed in this study limits our results about the factorial structure of the

Table 3
Correlations among the domains scores and total score on the AdAS Spectrum scale.

AdAS Spectrum scale Domains	Pearson's coefficients 1	2	3	4	5	6	7	Total score
1 Childhood/Adolescence	–							
2 Verbal Communication	.45*	–						
3 Non-Verbal Communication	.59 *	.57*	–					
4 Low Empathy	.37*	.51*	.44*	–				
5 Inflexibility and Adherence to Routine	.42*	.51*	.48*	.36*	–			
6 Restricted Interests and Rumination	.43*	.52*	.60*	.36*	.52*	–		
7 Hyper/Hyporeactivity to Sensory Input	.36*	.46*	.48*	.29*	.36*	.56*	–	
Total score	.68*	.73*	.83*	.57*	.85*	.83*	.69*	–
Mean	6.21	4.72	8.43	2.90	13.38	8.09	3.70	47.43
SD	3.27	2.65	4.26	1.96	5.83	4.02	2.68	18.93

Note: SD = standard deviation.
* $p < .001$, $n = 395$.

Table 5
Differences across university courses in domains and total scores on the AdAS Spectrum scale.

AdAS Spectrum scale Domains	Social/Humanities (n = 181) Mean (SD)	Science/Technology (n = 214) Mean (SD)	Student's t-test t (393)	p	d
Childhood/Adolescence	5.66 (3.35)	6.67 (3.13)	−3.09	.002	.31
Verbal Communication	4.19 (2.79)	5.17 (2.44)	−3.72	<0.001	.38
Non-Verbal Communication	7.80 (4.22)	8.96 (4.23)	−2.74	.006	.27
Low Empathy	2.52 (1.97)	3.23 (1.90)	−3.64	<0.001	.37
Inflexibility and Adherence to Routine	12.28 (6.17)	14.32 (5.37)	−3.52	<0.001	.35
Restricted Interests and Rumination	7.05 (4.09)	8.98 (3.75)	−4.88	<0.001	.49
Hyper- and Hyporeactivity to Sensory Input	3.39 (2.61)	3.96 (2.71)	−2.12	.034	.21
Total score	42.88 (19.96)	51.29 (17.13)	−4.50	<0.001	.45

Note: SD = standard deviation, d = Cohen's effect size.
n = 395.

AdAS Spectrum. Future work with community and larger samples (i.e. with different age ranges) and with assessment of pre-morbid risk factors would be needed in order to thoroughly test whether the seven-factor model fits the data at the item level, and to enhance the generalizability of our results. Moreover, deeper and more specific psychometric work at the item level would be also necessary to shorten the scale, thus making it a leaner and easier instrument for clinicians. Finally, although the overall lack of gender differences in the AdAS Spectrum scores would seem to suggest that the scale is sensitive enough to enable detection of SATs in male and female respondents, an analysis of measurement invariance across genders would be needed. Indeed, measurement invariance corresponds to the ability of a test to measure a specific construct in the same way across different groups of respondents. This is a central property of a test, because if an instrument does not measure a construct in the same way in different groups of respondents, the comparison of test scores between different groups of individuals has to be considered invalid (Waiyavutti et al., 2011). Invariance should be also investigated across clinical and non-clinical samples and across different and specific clinical groups, in order to support further the usefulness of this instrument. In this way, it would be possible to use the AdAS Spectrum to distinguish and characterize subgroups of subjects according to their scores. Finally, to explore whether the AdAS Spectrum performs well in relation to the underlying theory, prospective studies are needed to determine whether the AdAS scores do increase the risk for mental disorders, as the model hypothesizes.

In spite of the above limitations, overall this study provides evidence for the adequacy of the AdAS Spectrum in the general population from a psychometric point of view. Thus, it can be a promising tool that could help clinicians in early diagnosis and prevention. In fact, since the AdAS Spectrum is focused not only on the core features associated with diagnostic criteria for ASD, but also on isolated and atypical subthreshold symptoms, this instrument can be employed to assess the risk for prodromic forms of the autistic spectrum. Additionally, as there seems to be a continuous distribution of autism dimensions across different mental disorders, the AdAS Spectrum can be used to assess subthreshold autism spectrum in patients with different mental disorders. As such, given that the underlying theoretical approach of the instrument is dimensional and broad, it could be useful for identifying different and specific pathways of autism spectrum in the general population.

Declaration of competing interest

All authors declare that they have no conflict of interests.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2019.112576.

Appendix A

AdAS Spectrum

Instructions: The following questions refer to feelings or experiences you may have had in the past or that you may be experiencing currently. Please answer each of the questions by circling “YES” or “NO.” Please note that not all the questions refer to symptoms of an illness.

CHILD/ADOLESCENCE

When you were a child:			
1	Did gestures of affection (caresses, hugs, kisses) from relatives or friends ever make you feel uneasy?	YES	NO
2	Did you ever make a series of rituals before going to sleep (for example, placing shoes, clothes, books or toys in a particular position), saying goodnight or praying in a particular way, or did you have to listen to a certain story?	YES	NO
3	Were you ever extremely careful about your school books, exercise books or toys and did not like others to borrow or even touch them?	YES	NO
4	Did you ever devote most of your free time to isolated activities (e.g., videogames or books)?	YES	NO
5	Did you have few friends?	YES	NO
6	Were you always in search of the ideal friend?	YES	NO
7	Were you very possessive of your friends, seeking an exclusive relationship with them?	YES	NO
8	Were you an obstinate, stubborn child?	YES	NO
9	Did you particularly love to collect objects?	YES	NO
10	At school did you ever avoid eating or playing or doing gymnastics with other children?	YES	NO
11	Did you ever suffer from head-aches or stomach-aches in social situations or at the thought of having to face social situations?	YES	NO
12	Would you have preferred not to go to school, and study at home alone?	YES	NO
13	Were you ever extremely selective in your friendships, considering almost all other children to be unintelligent and/or too superficial?	YES	NO
14	Was it ever difficult for you to establish new friendships, take part in a group, play team-games?	YES	NO
15	Were you very quiet and sometimes unable to speak at all?	YES	NO
16	Do you remember, or has anyone ever described you as being talented in particular fields (e.g., music, mathematics, chess)?	YES	NO
17	Do you remember, or has anyone ever told you, that you were talented in some fields but that you performed poorly in others?	YES	NO

18	Did you ever try to avoid performing in public?	YES	NO
19	Were you ever teased by school-mates or bullied?	YES	NO
20	Have you ever bullied anyone or been cruel to animals or weaker companions?	YES	NO
21	Did you call your parents by name instead of calling them “mom” and “dad”?	YES	NO

VERBAL COMMUNICATION

The following questions refer to feelings or experiences you may have had during your life			
22	Do you tend to not speak much and/or use very short sentences?	YES	NO
23	Do you usually speak in a very low voice or in too loud a voice, or in a strange or monotonous way?	YES	NO
24	Do you ever say what you think, only to understand later that you have offended someone?	YES	NO
25	Has it ever been pointed out that you make inopportune statements and/or behave in a unusual or odd way?	YES	NO
26	Does it often happen that you don't get jokes?	YES	NO
27	Have you ever noticed, or has anyone ever pointed out that other people do not find funny or are not impressed by the jokes you like?	YES	NO
28	Do you tend to repeat jokes, even though they make no-one laugh?	YES	NO
29	Are you given to taking things literally?	YES	NO
30	Do you have difficulty in immediately grasping the broad sense of a certain expressions (for example, “a hen-pecked husband”, “a face like the back of a bus”)?	YES	NO
31	Does the expression “put yourself in my shoes”, especially if coming from a person of the opposite sex, make you laugh or seem totally meaningless to you?	YES	NO
32	Do you have difficulty in ending a conversation once started?	YES	NO
33	Do you ever quote phrases heard in films or read in books?	YES	NO
34	Do you find it hard to intervene in a conversation?	YES	NO
35	Is speaking in public particularly stressful for you?	YES	NO
36	Do you absolutely avoid speaking in public?	YES	NO
37	Do you ever butt into a conversation inopportunely?	YES	NO
38	Do you ever talk to yourself, asking and answering questions?	YES	NO
39	Do you distinctly prefer communicating via e-mail or text messages rather than speak to someone on the phone or in person?	YES	NO

NON-VERBAL COMMUNICATION

40	Do you feel uncomfortable if someone looks at you insistently?	YES	NO
41	Do you have difficulty looking others straight in the eye or not know where to look when talking to someone?	YES	NO
42	Have you ever been arrogant in order to hide your insecurity?	YES	NO
43	Have you ever dreamed of being naked?	YES	NO
44	Are you considered a very touchy person?	YES	NO
45	Are you the sort of person who does not worry about maintaining friendships or sentimental relationships?	YES	NO
46	Do you tend to hunch your shoulders and bow your head?	YES	NO
47	Do you regret not knowing how to dance elegantly and without feeling inhibited?	YES	NO
48	Are you good at taking off acquaintances or famous people?	YES	NO
49	Do you ever take on a role to feel more at ease when interacting with other people?	YES	NO
50	Have you ever used alcohol, anxiolytics or drugs to get over a disappointment or failure, or in order to help you face an important event?	YES	NO
51	Have you ever flared up in a rage without reason?	YES	NO
52	Do you feel more at ease without people around you at work or in a private setting?	YES	NO
53	Have you ever thought that certain situations can influence other ones, even if totally unconnected, (for example, “If I put my left foot down first when I get out of bed, it'll be a nice day”)?	YES	NO
54	Do you envy successful people, leaders or those who are generally approved of by others?	YES	NO
55	Do you often invent excuses or even tell lies in unimportant situations?	YES	NO
56	Have you ever invented a situation or a story in order to put yourself in a better light?	YES	NO
57	Do you have difficulty in doing even simple things if someone is watching you (such as talking on the phone, eating or writing?	YES	NO
58	When you have to do something in public, (for example, speaking), do you have to be absolutely perfectly prepared?	YES	NO
59	At work do you often say you are busy even when you have nothing to do?	YES	NO
60	Do you feel uneasy about hugging, kissing or holding someone you like by the hand?	YES	NO
61	In general, do you like being naked at home or going to nudist camps?	YES	NO
62	Do you avoid taking up sentimental relationships for fear of being rejected?	YES	NO
63	Is it easier for you to have sexual intercourse rather than get involved in an intimate emotional relationship with a partner?	YES	NO
64	Do you often fantasize about or have you ever been involved in non-conventional or illicit sexual relationships?	YES	NO
65	Do you prefer to not confide in anyone regarding your most intimate thoughts?	YES	NO
66	Do you spend a lot of time playing videogames or surfing on internet, to the extent of forgetting to do routine tasks?	YES	NO
67	Do you like role-playing so much that you identify yourself with your character to the point of living a second life?	YES	NO

LOW EMPATHY

68	Have you ever felt more attached to your pet than to other people?	YES	NO
69	Have you ever felt much more attached to an object than to other people?	YES	NO
70	Have you ever been involved in impossible sentimental relationships or with people already involved with others or who are much younger/older than you?	YES	NO
71	Have you ever been told that you are rather inhibited, or cold or too detached towards others?	YES	NO
Is it difficult for you:			
72	identifying with someone else?	YES	NO
73	understanding the intentions or thoughts of the person in front of you?	YES	NO
74	identifying with the protagonists of a book or film, and feeling what they feel?	YES	NO
75	understanding the intentions of the characters in a book or a film?	YES	NO
76	understanding when someone is flirting with you?	YES	NO
77	understanding if someone is interested in or bored by what you are saying?	YES	NO
78	interpreting the facial expressions and body language of others?	YES	NO

79	imagining what others expect from you?	YES	NO

INFLEXIBILITY AND ADHERENCE TO ROUTINE

80	Do you have difficulty in getting rid of useless objects such as used-up pens or newspapers that have been read?	YES	NO
81	Do you collect objects of value as well as useless things?	YES	NO
82	Do you feel compelled to finish a collection once you have started it?	YES	NO
83	There is an object that you would never separate from and that you want to carry with you all the time?	YES	NO
84	Are you excessively careful about aesthetical aspects (for example, matching colours, taste in clothes or furnishing?)	YES	NO
85	Have you ever felt compelled to repeat a certain action (like wringing your hands, twisting an object or a lock of hair between your fingers) or say certain words without any precise reason?	YES	NO
86	Have you ever felt compelled to repeat (even only mentally) a word or phrase that particularly struck you?	YES	NO
87	Have you ever felt compelled to walk in a particular way?	YES	NO
88	Do you ever feel the need to touch repeatedly an object or a part of your body without any apparent reason?	YES	NO
89	Do you tend to control every movement of your body?	YES	NO
90	Have you ever felt compelled to clear your throat before speaking or make certain movements with your hands before writing or knocking on the door?	YES	NO
91	Have you ever felt the need to repeatedly clean some areas of the house while neglecting others, e.g., meticulously cleaning the sink but overlooking the rest of the bathroom?	YES	NO
92	Are you particularly irritated by the use of certain popular words or catch-phrases like “Bob's your uncle!”, “Cheerio” or “Well, I never!”?	YES	NO
93	Are there any vowels or consonants or certain numbers that you particularly dislike?	YES	NO
94	Are you in the habit of inventing words and puns?	YES	NO
95	When you are telling a joke, do you alter your voice and accent according to the character?	YES	NO
96	When you are subject to a lot of stress, can you calm yourself down by making circular movements or by rocking yourself on a chair?	YES	NO
97	Do you need to think about something carefully before making a decision?	YES	NO
98	At work, do you prefer to follow precise procedures or patterns?	YES	NO
99	Are you headstrong and always do things your way?	YES	NO
100	Do you always wear the same type of clothes?	YES	NO
101	Do you rarely make changes to your aims in life even when it would be advisable to do so?	YES	NO
102	Do you have to make a list of the things to do every day?	YES	NO
103	Do you write lists to remember the principles you want to follow or behavior you want to adopt?	YES	NO
104	Are you unsettled by unexpected events (for example, last-minute invitations)?	YES	NO
105	Are you not really willing to change your daily habits?	YES	NO
106	Do you have sexual intercourse following precise routines (e.g., only on certain days of the week, in certain places or at certain times)?	YES	NO
107	Do you have difficulty in changing your mind about something even in front of evidence to the contrary?	YES	NO
108	Have you often had difficulty in changing your way of reacting and/or your methods of working even when there might be a better approach?	YES	NO
109	Have you often had difficulty in adapting to the different characters of people?	YES	NO
110	Have you often had difficulty in understanding the nuances of things, tending instead to be categorically ‘black or white’, ‘all-or-nothing’, ‘good or bad’?	YES	NO
111	Have you often had difficulty in lending or borrowing clothes, books, records or other personal objects?	YES	NO
112	Have you often felt the need to impose your ways of doing things and your habits on friends and family members (for example, your idea of cleanliness, your routines)?	YES	NO
113	Are you the type of person who is not prepared to compromise with regard to moral questions?	YES	NO
114	Are you very observant of the rules of etiquette?	YES	NO
115	Are you particularly fascinated by military parades or uniforms?	YES	NO
116	Are you one of those people who has to have everything in the house, or in the office, always in exactly the same place?	YES	NO
117	Have you ever been aggressive because other people wanted to stop you from carrying out your rituals or because they did not let you have your own way?	YES	NO
118	If you notice something wrong, even if it does not concern you directly, do you feel obliged to intervene (e.g., writing to the newspapers or on Facebook)?	YES	NO
119	Do you tend to get irritated when you lose things you are fond of?	YES	NO
120	Have you ever been told you behave too formally and stand on ceremony?	YES	NO
121	Have you ever thought that to get along well with other people there should be a precise set of rules to respect?	YES	NO
122	Do you have difficulty in changing your opinion about someone you hold very much in esteem, despite proof of his/her unreliability?	YES	NO

RESTRICTED INTERESTS AND RUMINATION

123	Do you particularly admire one or more famous celebrities (collecting posters, gadgets, photos and interviews)?	YES	NO
124	Do you like talking only to people who share your same specific interests?	YES	NO
125	Are you particularly good at picking up detail (e.g., parts of objects, parts of the body etc.)?	YES	NO
126	Do you like to think and talk only about the few things that interest you?	YES	NO
127	Do you try to avoid social occasions (e.g., dinners, parties, weddings, etc.) because you consider them to be a waste of time, and because you feel uneasy with people who talk about trivial things?	YES	NO
128	Do you sometimes have a thought or a topic fixed in your mind to the point that you cannot stop talking about it even when others do not seem at all interested?	YES	NO
129	Is it rare for you to find the topics preferred by most other people interesting or appealing?	YES	NO
130	Do you have the impression your thoughts are stored in your memory as if they were indexed in an archive?	YES	NO
131	Does it often happen that you are absorbed in something to the point of completely losing track of everything else?	YES	NO
132	Are you fascinated by numbers (e.g., dates, car registration plates, public transport time-tables etc.)?	YES	NO
133	Do you like to collect systematic information about certain things (e.g., types of cars, aeroplanes, trains, plants or animals)?	YES	NO
134	Do you tend to have very strong interests and does it bother you deeply if you cannot pursue them?	YES	NO
135	Do you always try to put your reasoning or your observations in order?	YES	NO
136	Have you ever been described as or have you ever considered yourself to be someone with little capacity to be concise in your work or study as you tend to waste time over detail?	YES	NO
137	Do you regularly arrive late for appointments because you lose track of time?	YES	NO
138	Do you tend to brood over the same matters or the same thoughts?	YES	NO
139	Do your thoughts often take up all your attention, leaving you unable to do anything else?	YES	NO
140	Do you often continue to ponder over things even in the case of problems which do not have an answer?	YES	NO
141	Do you often have difficulty in falling asleep because you cannot stop thinking?	YES	NO
142	Do you insist on a particular way of doing things, taking up more time than would be normal to complete a task, and you are never satisfied with the result?	YES	NO

143	Do you often take refuge in fantasizing or day-dreaming?	YES	NO

HYPER-HYPO REACTIVITY TO SENSORY INPUT

144	Have you ever perceived buzzing or low noises to be amplified or even unbearable?	YES	NO
145	Have you ever seen indistinct and threatening images in the shadows?	YES	NO
146	Have you heard other people's voices become suddenly strange and frightening?	YES	NO
147	While awake, have you ever felt strange, inexplicable sensations on your skin and in your body (e.g. the feeling of being touched, or wet or run through by an electric current)?	YES	NO
148	While awake, have you ever perceived noises, or odours or flavours that no-one else could perceive?	YES	NO
149	Do you avoid passing through or stopping in noisy places?	YES	NO
150	Do you think you have a low pain threshold, for example when you get injured or cut?	YES	NO
151	Do you think you have a high pain threshold, for example when you get injured or cut?	YES	NO
152	Have you ever suffered from aches for which you referred to physicians but for which nobody was able to find a cause?	YES	NO
153	Do you sometimes shut yourself away in total darkness because the light even though barely filtering through closed shutters unsettles your mood and/or concentration?	YES	NO
154	Have you ever been convinced that you possess unusual abilities or that you have had particularly unusual experiences?	YES	NO
155	Is the physical sensation of food in your mouth more important than the actual taste?	YES	NO
156	Are some common fabrics unpleasant or irritating to you on your skin?	YES	NO
157	If you find yourself in an environment full of noise, smells and bright lights, do you feel uneasy, anxious or frightened?	YES	NO
158	Have you ever happened to feel immobilized, like a block of ice, without being able to respond to being called for hours or days?	YES	NO
159	Do you happen to hear also low noises which other people cannot hear?	YES	NO
160	Do you sometimes have difficulty in washing and need to be prompted to do so?	YES	NO

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