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Using the Ritvo Autism Asperger Diagnostic Scale-Revised (RAADS-R) disentangle the heterogeneity of autistic traits in an Italian eating disorder population

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ABSTRACT

Background: In recent years it has been suggested that eating disorders (ED) and autism spectrum disorders (ASD) could share common difficulties and cognitive style. Recent epidemiological studies found that about 25% of women with anorexia nervosa (AN) reached the cut-off in screening questionnaires for ASD. The present study aimed to assess the heterogeneity of ASD traits in an ED population and extend previous results to ED other than AN in the DSM-5 era.

Methods: We assessed all new outpatients (N = 71) aged 15 or older, admitted over an 8-month period to a specialized ED hospital ward. After admission, they completed two self-report questionnaires, and received a clinical assessment for ASD, supported by the Ritvo Autism Asperger Diagnostic Scale Revised (RAADS-R) used as a structured clinical interview. The responses to each of the items, subscales, full scales and DSM-5 criteria were examined separately for discriminatory power between patients with high ASD traits (HAST) and low ASD traits (LAST).

Results: Thirty-three percent of patients with ED (20% with narrowly defined AN) were classified as HAST, with no significant difference between the ED categories. Using RAADS-R, there was a high agreement among our modified algorithm, clinical judgment and DSM-5 criteria. The distribution of traits was indicative of two distinct populations with specific sets of traits clustering in the two groups.

Conclusions: If routinely undertaken, RAADS-R could be useful to disentangle the heterogeneity present in patients with ED. Separating the HAST and LAST groups could be useful for both clinical and research purposes.

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1. Introduction

Autism Spectrum Disorders (ASDs) are neurodevelopmental conditions characterised, according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013), by qualitative impairments in the social communication and restricted, repetitive behaviours domains.

Feeding and eating disorders (FED) are characterised by markedly abnormal attitudes toward body weight and food intake, which result in disturbed patterns of eating and behaviour. FED include eating disorders (ED) with an usual onset during, or after, adolescence (American Psychiatric Association, 2013).

At first glance, differences in on-set, diagnostic criteria and male-to-female ratios (5:1 for ASD and 1:10 for ED; Christensen, 2016; Rosenvinge & Pettersen, 2015) work against a link between ASD and ED, but several studies have found common traits in the two conditions.

1.1. Link between ASD and ED

A recent meta-analysis (Westwood et al., 2015) of seven studies, using the Autism Quotient (AQ) self-report questionnaire (Baron-Cohen et al., 2001), showed that patients with AN appear to have typical ASD difficulties, especially in terms of social skills, attention switching and communication, compared to controls.

Studies in ED also found differences in neurocognitive or behavioural traits, suggesting characteristics similar to ASD such as social communication difficulties (Anckarsäter et al., 2012), friendship difficulties (Doris, Westwood, Mandy, & Tchanturia, 2014), poor social functioning (Tchanturia et al., 2013), social anhedonia (Harrison, Mountford, & Tchanturia, 2014), impaired theory of mind skills (Russell, Schmidt, Doherty, Young, & Tchanturia, 2009;Gillberg et al., 2010; Oldershaw, Treasure, Hambrook, Tchanturia, & Schmidt, 2011), alexithymia (Brewer, Cook, Cardi, Treasure, & Bird, 2015; Bird & Cook, 2013) and abnormal facial expression to emotional stimuli (Davies et al., 2016), difficulty with set-shifting (Westwood, Stahl, Mandy, & Tchanturia, 2016) and weak central coherence (Lang et al., 2014). Many of those cognitive traits are shared between different categorical diagnoses, therefore, there is no agreement yet as to the extent to which those traits can be considered characteristics of ED and, even less so, characteristics of a specific kind of ED. Moreover, neurocognitive and psychological studies usually report only central tendencies (e.g. means) and standard deviations when comparing clinical and control groups; however, in order to develop personalised treatments, we should address the heterogeneity in ASD traits observed in clinical practice.

A systematic review (Huke, Turk, Saeidi, Kent, & Morgan, 2013). included seven studies of ED populations done during the period of DSM-IV showing prevalence rates for participants scoring over the ASD cut-off of between 18% and 37% (mainly using The Asperger Syndrome –and high-functioning autism- Diagnostic Interview –ASDI; Gillberg, Gillberg, Rastam, & Wentz, 2001). A more recent study (Mandy & Tchanturia, 2015) used the Autism Diagnostic Observation Schedule (ADOS) module 4 (Lord, Rutter, DiLavore, & Risi, 2002). The sample consisted of adolescents with different EDs and with suspected ASD. Five out of 10 scored in the ASD range on the ADOS, and another two were judged to have ASD on the basis of clinical observation. Nevertheless, only one had a childhood diagnosis of ASD.

From a different angle, similar results were obtained studying ED in patients with ASD. Using the Eating Attitude Test (EAT-26; Garner, Olmsted, Bohr, & Garfinkel, 1982) to assess ED, more girls with ASD (26.8%) than typically developing girls (7.1%) scored over the cut-off (Kalyva, 2009). A recent study with 119 adults with ASD (Karjalainen et al., 2016) reported an 8% presence of a diagnosed ED (1 BED, 2 BN, 6 AN), but, when a smaller sample (59% males) completed the EAT-26, 18% (9% severe) of them scored over the cut-off.

To sum up, previous neurocognitive studies have suggested shared traits between ED and ASD, and categorical studies have suggested an underdiagnosis of ED in ASD and of ASD in ED. However, it is unclear how ASD traits are related to ED and if the previous categorical results, mainly obtained with AN patients, can be extended to other EDs. ASD traits in ED can be (a) a shared and family related cognitive phenotype, with the same traits predisposing the person to the development of both conditions (Kothari et al., 2015); (b) a consequence of ED due to the effects of malnutrition on the brain or the exacerbation of comorbidities (for instance women who have recovered from AN show a profile that is midway between the acute phase and normal participants; Morris, Bramham, Smith, & Tchanturia, 2014; Tchanturia et al., 2012; Harrison, Tchanturia & Treasure, 2010); (c) a comorbidity developed by undiagnosed people with ASD (Rastam & Wentz, 2014).

The present paper presents the results of a clinical and research project conducted in the Eating Disorder hospital ward at "Santa Maria della Pietà" in Rome. The objectives were to find an instrument able to discriminate between sub-populations with a high level of ASD traits (HAST) and a low level of ASD traits (LAST), to find their relative prevalence and to study the ASD characteristics of those different populations. If an instrument can be chosen to easily assess the heterogeneity of ASD traits in ED, it could inform future research on comparing treatment outcome in individuals with high and low levels of ASD traits.

1.2. Objectives and hypotheses

Many previous studies have focused on AN and were done before DSM-5. We aimed to extend prevalence estimates to other ED categories and to use DSM-5 criteria for both ASD and ED. We did not expect a large effect size for HAST prevalence

between AN and other ED. The power analysis suggested that 52 subjects were enough to reveal an effect size $d > 0.8$, with power $(1 - \beta)$ set at 0.80 and $\alpha = 0.05$, two-tailed.

In order to discriminate between the HAST and LAST categories we aimed to: (a) study the discriminatory power of The Ritvo Autism Asperger Diagnostic Scale Revised (RAADS-R; Ritvo et al., 2011) and our modified algorithm, (b) check the categorization differences against clinical judgment and DSM-5 criteria, (c) find thresholds for a combined RAADS/DSM-5 algorithm. We expected good accuracy for RAADS-R and better accuracy for the modified algorithm. In order to consider the two groups as two different clinical populations we not only needed to assess their average cluster distance, but also the presence of traits specific to the population with HAST. For that reason, we expected the presence of a group of items on RAADS-R that showed a very large effect size in discriminating between the two groups. Finally, we expected the presence of a worsening in the symptomatology due to comorbidities to be revealed by the "worsening" category. Accordingly, we expected a correlation between RAADS-R and comorbidities, but a small to null effect of comorbidities for our modified algorithm. We further explored the link between ED and ASD traits through self-report questionnaires. We expected a higher score on self-report questionnaires AQ and Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004) for HAST than for LAST. Given the exploratory nature of the single-item and subscale study, we did not make any directional assumptions for them, and we corrected for multiple comparisons.

2. Method

2.1. Participants: sampling procedures and inclusion criteria

Inclusion criteria: (1) age 15 or older, (2) being admitted to the clinic for the first time, (3) receiving a diagnosis for an ED according to DSM-5, (4) not having knowledge of the research before admission to the ward.

During the 8-month sampling period, 71 patients fulfilling criteria 1 and 2 came to the ward and received a clinical assessment. Four participants were excluded from the data analysis: two patients (1 male) had received an ASD diagnosis in adulthood and were referred to the ward to assess a comorbid ED by a specialist informed about our research protocol, and two male patients came due to obesity, that according to DSM-5 is not an ED. The final 67 participants' characteristics are shown in Table 1. All were female, and none showed features of intellectual disability during the examinations or had it mentioned in their clinical or academic records.

2.2. Ethics

All of the data were gathered primarily to inform clinical care. Participants gave informed consent, during intake, for the use of their clinical records for research, and we have protected their privacy and confidentiality by ensuring that information from the clinical records remains anonymous. The research was approved by the ethics committee of the ASL Roma 1, in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

2.3. Clinical assessment

All participants had their first evaluation during a clinical interview with a psychiatrist, a psychologist, and a dietician working in the ward, in order to receive an ED diagnosis and to be assessed for co-morbid symptomatology. Each participant took the Eating Disorder Inventory – 3 (EDI-3; Garner, 2004), the Body Unease Test (BUT) (Cuzzolaro, Vetrone, Marano, &

Table 1
Age and Body Mass Index (BMI) in Different Subgroups.

Factor	Group	n	Mean (*SE*)	95% *CI*	Mdn (*IR*)	Min	Max
Age	*Total**	67	22.9 (0.9)	21.1–24.7	21.1 (9.5)	15.0	45.7
	LAST*	45	23.9 (1.1)	21.0–25.4	22.4 (10.5)	15.0	45.7
	HAST*	22	20.9 (1.5)	17.8–24.0	17.7 (7.4)	15.1	44.4
	*AN**	29	19.8 (1.0)	17.7–21.9	18.0 (5.0)	15.1	43.7
	BN	25	24.5 (1.6)	21.1–27.9	22.5 (12.5)	15.0	45.7
	BED	13	27.0 (1.9)	22.8–31.2	26.4 (8.5)	15.9	39.8
BMI	*Total**	67	21.3 (0.7)	19.9–22.6	20.0 (5.6)	13.1	43.3
	LAST*	45	21.1 (0.9)	19.3–22.8	20.0 (6.2)	13.1	43.3
	HAST	22	21.7 (1.1)	19.5–23.9	20.3 (6.1)	14.2	33.4
	AN	29	17.7 (0.5)	16.7–18.6	17.1 (3.4)	13.1	25.3
	*BN**	25	21.6 (0.7)	20.2–23.0	20.8 (3.1)	17.8	21.4
	BED	13	28.8 (1.7)	25.1–32.4	27.9 (9.2)	21.3	43.3

*The distribution is not normal.
In the table are reported the scores for the groups with high autism spectrum traits (HAST) and low autism spectrum traits (LAST), and for the eating disorder categories: anorexia nervosa (AN), bulimia nervosa (BN) and binge eating disorder (BED).

Garfinkel, 2006) and the Symptom Checklist-90 (SCL-90) for general psychopathological symptoms (Derogatis & Melisaratos, 1983).

The participants were asked to complete (optionally) the AQ and the EQ questionnaires at home during the interval between the first and the second visit.

During a second interview (different day, same week), the participants were evaluated for ASD by a clinical psychologist with 10 years of experience in the field. During this interview, the psychologist used RAADS-R as a clinical structured interview to prompt discussion of the participant's life experiences and specific symptoms. Before endorsing any ASD trait, the examiner waited for reports of at least two examples of that behaviour. The participants' answers where marked directly by the psychologist while other examples and comments where annotated on a separate sheet. The examiner was blind to previous test results.

Clustering in the HAST and LAST groups was established, based on the team observations, questionnaires and, when available, informants' reports and previous clinical records.

2.4. Difficulties in assessing ASD in adults and in people with ED

A rigorous diagnosis of ASD can be difficult to obtain in a population that is almost entirely female, adult, with mild ASD symptoms and usually without a childhood diagnosis. Thus, we separated our participants into two specific groups, i.e. high and low ASD trait groups. This approach allowed us to split a heterogeneous population into two more homogenous groups, in order to guide future clinical trials that compare different intervention and research looking at the cognitive phenotype.

Females with ASD are often diagnosed later, or not at all, unless they have a significant intellectual disability (Hiller, Young, & Weber, 2015). They show better social skills and motivation than males (Kuo, Orsmond, Cohn, & Coster, 2013), fewer stereotyped behaviours and narrow interests, which in turn are either less intense and pervasive, or more in line with those shown by their typical peers (Begeer et al., 2013; Head, McGillivray, & Stokes, 2014). Clinicians and adults with ASD have highlighted the ability to camouflage ASD social difficulties through imitation of typical behaviours; nevertheless, the effort of suppressing autistic behaviours and concealing social difficulties frequently leads to cognitive and emotional exhaustion (Bargiela, Steward, & Mandy, 2016; American Psychiatric Association, 2013; Attwood & Grandin, 2006)

ADOS is considered to be a "gold standard" for ASD diagnosis but was developed primarily for children with autistic disorder and was followed by ADOS module 4 which was refined to assess the continuity of traits in verbally fluent adults. Nevertheless, it does not show the specificity and sensitivity we need in discriminating adults with comorbidities and no previous diagnosis (Bastiaansen et al., 2011; Lai et al., 2011; Lever & Geurts, 2016; de Bildt, Sytema, Meffert, & Bastiaansen, 2015) or the range of items needed to capture the subtle and diverse traits frequently present in adults with mild symptoms (Eriksson, Andersen, & Bejerot, 2013). It would also be difficult to routinely integrate it in adult psychiatry protocols because it requires extensive and specific training and, as an observation schedule, has a format that is too different from the interviews usually used in those settings.

For those reasons we choose RAADS-R as our primary instrument of investigation.

RAADS is an empirically derived structured clinical interview tailored to assist in the diagnosis of adults with mild ASD (Asperger Syndrome and High Functioning Autism) with average or above-average intelligence. The scale was designed for clinical use in a clinical setting (RAADS; Ritvo et al., 2008). A discussion of the items with the patient may clarify any ambiguities regarding the statements and provide a fuller clinical understanding of the patient's symptoms. The RAADS response scale has four qualitative alternatives: "never true," "true only when I was young (before the age of 16)," "true only now," and "true now and when I was young", to provide a picture of how the symptoms have progressed during the patient's life span. Autistic symptoms during childhood are required for the ASD diagnosis but, when it is impossible to recollect information from parents or other sources, a clinical diagnosis can be made asking the patient to recall her own childhood (American Psychiatric Association, 2013; Eriksson et al., 2013). RAADS-R was validated as a structured clinical interview in two multicentre studies comparing participants with ASD, individuals with typical development and with other psychiatric disorders (Andersen et al., 2011; Ritvo et al., 2011). RAADS-R showed an excellent sensitivity (.91-0.97) and specificity (0.93–1.00) and a large discriminatory power between groups with ASD and without ASD on every single item.

We suggest that RAADS-R could be modified in agreement with DSM-5 and could be suited to measuring the level and heterogeneity of ASD traits amongst ED service users.

2.5. Adaptation of RAADS-R

The Italian version of RAADS-R (Moscone & Vagni, 2013) is available online and was linguistically validated according to the methodology explained by Wild and colleagues (2005).

Two expert psychologists independently investigated the 80 items of RAADS-R looking for congruency with the ASD criteria in DSM-5. Even when the clinicians' categorisation on an item differed, they reached a consensus after discussion (table S.8 in Supplementary materials).

We also used this instrument with 15- to 18-year-old females, beyond the original validation. That is why we removed the specification of "<16 years old" in the "Only when I was younger" category, and if the clinician was asked by the patient about a specific time frame, he replied "before you started having significant difficulties with eating behaviours." Given the possible issues with sensitivity for adolescents and young adults (Ritvo et al., 2011), we controlled for age differences in the scores.

Item 72, "I enjoy spending time eating and talking with my family and friends", was modified to, "I enjoy spending time meeting and talking with my family and friends", to retain the original social meaning without interference from ED.

To analyse the effect of ED on ASD traits, we re-mapped the data from RAADS-R, creating four categories linked to the answer endorsed by the participants: ASD-like, Worsening, Improving and Typical.

The original scoring algorithm could lead to a false positive if we expected a worsening of ASD traits due to comorbidities. To avoid that, we developed an alternative scoring algorithm, setting to 0 answers suggesting a worsening of symptoms and setting to 2 ASD-like answers to reduce the possible difference due to young age (score range: 0–160; Table 2). In the following sections, the modified algorithm is indicated by RAADS-M (modified).

2.6. Statistical methods and analysis

For each test, we assessed normality by using the Kolmogorov-Smirnov Test of Normality with Lilliefors significance correction. When a variable could be considered normally distributed, we used an ANOVA to compute significance and effect size. Non-parametric tests were used when normality could not be assumed. For comparisons between two groups, the Mann–Whitney *U* test was used for continuous variables and the chi-square test was used for dichotomous variables. Correlations were computed using Spearman rho. Effect size *d* was approximated using a *z*-score to compute a non-parametric approximation (Fritz, Morris, & Richler, 2012). All significance tests were two-tailed, conducted at the 5% significance level and Sidak-corrected for multiple comparisons.

The sensitivity, specificity and accuracy of a test score to distinguish between HAST and LAST was computed using non-parametric ROC methods. The optimal threshold (cut-off) was defined as the minimum value of the given factor or the score that maximised accuracy, defined as the average of sensitivity and specificity. Cronbach alpha was computed to assess the internal consistency of the original and DSM-5 RAADS's subscales.

Because we used RAADS-R during the interview, comparing it to the clinical categorization could inflate sensitivity and specificity. However, RAADS-R accuracy was reported only to compare different algorithms and find the best cut-offs, but should not be considered to be a measure of the external validity of the instrument, or generalized to the use of RAADS-R as a self-report measure.

Cluster analysis was performed with the SPSS TwoStep clustering method to handle categorical variables. SPSS TwoStep extends the model-based distance measure used by Banfield and Raftery (1993) and uses a two-step clustering approach similar to BIRCH (Zhang, Ramakrishnan, & Livny, 1996). All statistical analyses were performed using SPSS for OSX, version 23.

3. Results

3.1. Characterization of the ED population and HAST prevalence

In the total sample, 30% had AN, 36% had bulimia nervosa (BN), 16% had binge eating disorder (BED) and 18% had an other specified FED (OSFED); none of the participants received an unspecified FED or purging disorder diagnosis. In order to increase the power of our analysis, we decided to collapse all OSFED categories (subclinical BN, subclinical BED and atypical AN) into their related ED, leading to a 43% prevalence of AN, 37% of BN and 20% of BED. All participants were females.

Three women received a second diagnosis of borderline personality disorder, and one also had drug addiction. Three women received the multicompulsive specifier, characterised by numerous and various compulsive behaviours, such as alcohol, drug abuse and self-injurious behaviours. Ten percent of the AN patients received the purging specifier, whereas 30% were restrictive only.

According to DSM-5 criteria and clinical judgment, 22 of the 67 participants (33%) were classified as HAST. HAST prevalence was 28% in AN (20% if narrowly defined), 40% in BN, 31% in BED (18% if narrowly defined). Overall prevalence was 29% in strictly defined ED and 50% in OSFED. The HAST frequency difference between AN and other EDs (BN and BED together), $x^2(2, N = 67) = 0.29$, $p = 0.59$, $d = 0.13$; BED, $x^2(2, N = 42) = 0.045$, $p = 0.83$, $d = 0.07$; or BN, $x^2(2, N = 54) = 0.46$, $p = 0.50$, $d = 0.19$, were not significant.

The distribution of body mass index (BMI) was the same in participants with HAST and with LAST ($U = 544$, $Z = 0.66$, $p = 0.51$, $r_{pb} = 0.08$, $d = 0.16$), but participants with HAST were younger ($U = 341$, $Z = 2.12$, $p = 0.04$, $r_{pb} = 0.26$, $d = 0.52$; Table 1).

Table 2
Ritvo Autism Asperger Diagnostic Scale Revised (RAADS-R) and Modified (RAADS-M) Scoring Algorithm.

Algorithm	Always	Only Now	Only when I was younger	Never
RAADS-R	3	2	1	0
Inverse Items	0	1	2	3
RAADS-M	2	0	1	0
Inverse Items	0	1	0	2

Table 3
RAADS Score for the Revised and Modified Scoring Algorithm.

Factor	Group	n	Mean (SE)	95% CI	Mdn (IR)	Min	Max
RAADS-R	Total*	67	75.2 (7.6)	60.0–90.4	62 (105)	0	224
	LAST*	45	38.0 (4.6)	28.6–47.4	29 (48)	0	124
	HAST	22	151.2 (7.2)	136.1–166.3	148 (59)	112	224
	*AN**	29	68.1 (10.4)	46.8–89.4	69 (100)	0	184
	*BN**	25	82.6 (13.9)	54.0–111.2	53 (116)	4	224
	BED	13	76.6 (18.0)	37.5–115.7	62 (107)	0	201
RAADS-M	Total*	67	45.3 (5.2)	40.0–55.6	24 (68)	0	150
	LAST*	45	18.6 (2.2)	14.1–23.2	16 (19)	0	55
	HAST	22	99.8 (4.8)	89.9–109.7	97 (36)	73	150
	*AN**	29	39.3 (6.8)	25.4–53.2	24 (68)	0	115
	*BN**	25	50.7 (9.6)	30.9–70.4	24 (81)	2	150
	BED	13	48.4 (12.3)	21.6–75.2	29 (74)	0	133

*The distribution is not normal.
In the table are reported the scores for the groups with high autism spectrum traits (HAST) and low autism spectrum traits (LAST), and for the eating disorder categories: anorexia nervosa (AN), bulimia nervosa (BN) and binge eating disorder (BED).

3.2. RAADS-R and RAADS-M classification

By using ROC curve analysis, we determined that the best threshold to distinguish between the two groups was a score of 106. Using this cut-off, all 22 participants with HAST were correctly classified (sensitivity = 1.00), and one participant with LAST scored over the threshold (124) (specificity = 0.98, accuracy = 0.99). The original RAADS-R cut-off of 65 still yielded a sensitivity of 1.00, but the specificity was 0.78. Only nine participants (13%) scored between 64 and 111, and 25% scored less than 19; the median was 62 (Table 3).

Using our modified scoring algorithm, the minimum threshold to distinguish between the two groups was a score of 56. Using this value, we obtained 100% accuracy; no participant scored in the 56–72 range. With the modified scoring algorithm, 30% of the participants scored less than 13, and the median score was 24 (Table 3). There was a negative correlation between age and RAADS-R, $r_s(67) = -0.27$, $p = 0.03$, or RAADS-M algorithm, $r_s(67) = -0.26$, $p = 0.03$, but not with BMI: RAADS-R, $r_s(67) = 0.12$, $p = 0.33$, and RAADS-M algorithm $r_s(67) = 0.11$, $p = 0.36$. RAADS-R and RAADS-M scores were not normally distributed (Fig. 1).

The correlation between the original and the new scoring algorithm was very high $r_s(67) = 0.974$, $p < 0.001$. Cronbach's alpha for the scale reliability was 0.978 for RAADS-R and 0.979 for RAADS-M. The difference between the HAST and LAST group was large for both algorithms (RAADS-R: $U = 6$, $Z = 6.53$, $r_{pb} = 0.80$, $d = 2.65$; RAADS-M: $U = 0$, $Z = 6.61$, $r_{pb} = 0.81$, $d = 2.74$). To control for the validity of the instrument further, we partitioned the data into two clusters, using the categorical TwoStep approach ("Always", "Never", "Worsening", "Improving"). A two-cluster solution was the best one according to the Bayesian information criterion (BIC) (Fraley & Raftery, 1998). The silhouette coefficient (Aranganayagi & Thangavel, 2007), which is a measure of both cohesion and separation, was fair (0.4). Distance between cluster centres was 9.8 using a K-means clustering with RAADS-M.

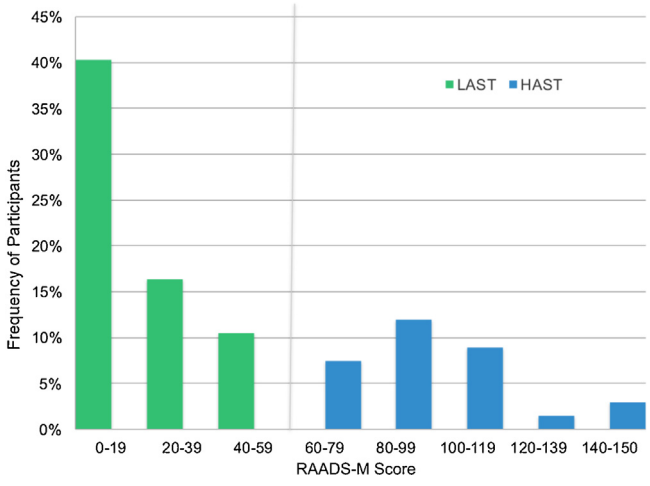

Fig. 1. RAADS-M Score Frequency Distribution.
The x-axis reference line separates LAST (green) and HAST (blue) groups. All participants in the LAST group scored less than 56 and all participants in the HAST group scored more than 72.

Table 4
Non Parametric Correlation Between RAADS-M Subscales.

Criteria	A.1	A.2	A.3	B.1	B.2	B.3	B.4	Total
A.1.Social-Emotinal Reciprocity	1	0.79	0.85	0.66	0.75	0.75	0.74	0.95
A.2. Non-Verbal Communication	–	1	0.75	0.57	0.74	0.69	0.61	0.84
A.3. Relationship and Social Context Understanding	–	–	1	0.68	0.74	0.69	0.70	0.89
B.1. Repetitive Behaviours	–	–	–	1	0.65	0.57	0.63	0.72
B.2. Insistence on Sameness	–	–	–	–	1	0.68	0.64	0.81
B.3. Interests and Cognitive Style	–	–	–	–	–	1	0.68	0.84
B.4. Sensory-Motor	–	–	–	–	–	–	1	0.83

All correlations are significant at the 0.001 level.

There was a 100% agreement between the two clustering methods and our clinical partitioning.

The Cronbach alpha coefficients for the original subscales were satisfactory (circumscribed interests = 0.918, language = 0.811, sensory motor = 0.912, social relatedness = 0.962), indicating good internal consistency.

3.3. DSM-5 criteria and RAADS-M

The seven clinically derived DSM-5 subscales showed good internal consistency using Cronbach alpha (.94-0.82), with the exception of the B.1 subscale that had only 3 items (.66). The correlation between subscales ranged from 0.57 to 0.85 ($p < 0.001$) and between subscales and the full scale ranged from 0.72 to 0.95 ($p < 0.001$) (Table 4). The difference between the HAST and LAST group was significant for each subscale ($1.9 < d < 2.8$, $p < 0.001$; Fig. 2).

Using DSM-5, to reach an ASD diagnosis a patient should meet all three criteria of dominion A and 2 out of 4 criteria of dominion B. In order to find thresholds for each criteria we started by requiring at least 2 definitive symptoms (RAADS-M score of 4 or more) with the exception of criterion B.1 because DSM-5 allows for the presence of stereotypes only in childhood. After that we increased the threshold of each subscale until maximum sensitivity was maintained (Table 5). With this DSM-5 algorithm we had 99% accuracy. Only one participant with HAST was left out due to a sub-threshold score on criteria A.2 (this participant was included in the HAST group because during the interview she showed other difficulties in non-verbal behaviour unaccounted for in RAADS).

3.4. Autistic traits in different subgroups

Complete statistical analysis for each RAADS, AQ, EQ item and SCL-90 subscales is reported in the Supplementary materials.

3.4.1. RAADS-M group distinctions

For RAADS-M, group difference was significant for 59 single items ($p < 0.00064$).

The Total score in AN was not significantly higher than in BN ($U = 405$, $Z = 0.75$, $p = 0.45$, $r_{pb} = 0.09$, $d = 0.19$) or BED ($U = 213$, $Z = 0.68$, $p = 0.50$, $r_{pb} = 0.08$, $d = 0.17$).

Eight items had a large effect size ($6.2 < Z < 7.5$, $2.3 < d < 4.6$), and the category "Always" was endorsed by more than 80% of participants with HAST and less than 20% participants with LAST. The two most discriminating items related to the lack of

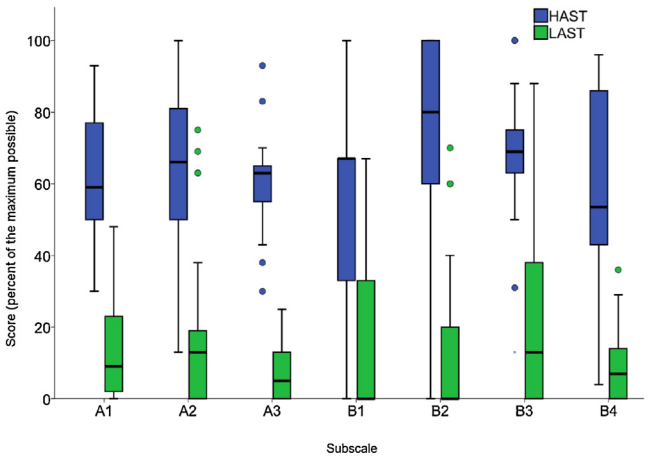

Fig. 2. Boxplot of HAST and LAST Scores on the Ritvo Autism Asperger Diagnostic Scale Modified (RAADS-M), DSM-5 Subscales.
All of the differences between the groups are significant at the 0.5% level after Sidak correction ($p < 0.001$). Category frequency is normalized by the total number of items within each Criteria and expressed as percentage.

Table 5
DSM-5 Thresholds and Subscales (DSM-5 Criteria) Accuracy for RAADS-M.

Subscale	Threshold for DSM-5 algorithm#	Computed RAADS-M Cut-off				Area Under the Curve		
		Value	Sen.	Spec.	Accuracy	Area	SE	95% CI
A.1	12	16	0.96	0.96	0.96	0.99	0.01	0.97–1.00
A.2	4	5	0.91	0.87	0.89	0.92	0.03	0.86–0.99
A.3	11	11	1.00	1.00	1.00	1.00	0.00	1.00–1.00
B.1	3	3	0.68	0.98	0.83	0.90	0.05	0.81–0.99
B.2	4	5	0.91	0.91	0.91	0.95	0.03	0.89–1.00
B.3	4	7	0.91	0.82	0.87	0.92	0.04	0.85–0.99
B.4	4	9	0.86	0.98	0.92	0.95	0.03	0.90–1.00
Total	–	56*	1.00	1.00	1.00	1.00	0.00	1.00–1.00

*56 is the minimum cut-off with a 100% accuracy. The average between minimum and maximum cut-off is 64. There were no participants' scores between 56 and 72.
In order to score RAADS-M according to DSM-5 algorithm subscales A.1, A.2, A.3 and at least 2 of the subscales B should be equal or greater than the threshold value.

interest in topics most people consider interesting and sensory overload (HAST > 95%, LAST < 10%) (items 52, 67). Another five items (2, 54, 58, 6, 64) related to social relatedness, especially the interpretation of non-verbal behaviour and turn-taking abilities. The last item (72) related to aloofness.

Another 8 significant items ($3.8 < Z < 5.7, 1.0 < d < 0.9$) were endorsed by less than 5% of participants with LAST and 40% to 70% of participants with HAST, such as asking embarrassing questions (item 79), especially when they were younger (improving in 32% of participants with HAST), understanding metaphors and figures of speech (items 7, 66), auditory hypersensitivity and avoidance (items 36, 57), difficulty with sensory modulation (items 34, 46) and the absence of pleasure from chatting with friends (item 43).

Only three RAADS-M items did not reach significance for the difference between the two groups before correction for multiple comparison (items 11, 38, 62; $p > 0.05$, $d < 0.43$), and most of the 21 items that did not reach significance ($p > 0.00064$, $d < 0.92$) after correction could be clustered into categories. Attention to details (items 40 and 9) was endorsed by the majority of participants (69% and 66%, respectively). Other items that were highly endorsed regardless of the diagnostic status related to voice regulation (items 4 and 62), difficulties with emotional perspective-taking (items 6, 15, 38) and the tendency to make *faux pas* (items 12, 80). Tactile defensiveness (items 19, 29), clumsiness (item 16) and memory (item 70) were endorsed by 20–40% of the total sample. Also, 50% of the participants judged themselves as unfriendly (item 1), whereas lack of affection and prosocial behaviours were seldom endorsed by both groups (items 18, 14, 11, 31, 48). The use of script in conversation was rarely endorsed, too (item 2).

3.4.2. RAADS, comorbidities and reported changes in time

In order to exclude the effect of comorbidities in classification and to verify the efficiency of the RAADS-M algorithm in avoiding them, we submitted both scoring algorithms to an ANOVA using SCL-90 subscale as a covariate. None of the single subscales had a significant effect. However, SCL-90 global scale significantly predicted RAADS-R scores, $b = 0.292$, $t(65) = 2.44$, $p = 0.017$, and explained a small but significant proportion of the variance $F(1, 65) = 5.98$, $p = 0.017$, $\eta^2 = 0.085$. Nevertheless, it does not predict RAADS-M scores, $b = 0.202$, $t(65) = 1.64$, $p = 0.104$, and $F(1, 65) = 2.72$, $p = 0.104$, $\eta^2 = 0.041$. Similar results held for RAADS-M when analysing the HAST and LAST groups separately, whereas the effect on the number of "worsening" symptoms endorsements was significant for the whole group, $F(1, 65) = 12.3$, $p = 0.001$, $\eta^2 = 0.162$, and for the LAST group, $F(1, 40) = 19.1$, $p < 0.001$, $\eta^2 = 0.314$, but not for the HAST group $F(1, 20) = 1.73$, $p = 0.210$, $\eta^2 = 0.077$. The Spearman correlation with RAADS-R was significant (after correction) for depression (.34), interpersonal sensitivity (.36), paranoid ideation (.36) and the global scale (.35), but no correlations reached significance for RAADS-M and there was no significant difference between HAST and LAST group on any SCL-90 subscale or its total score, $F(1, 65) = 0.97$, $p = 0.33$, $d = 0.26$.

To explore the chance of a pattern of response caused by ED, we analysed the ratio of negative symptomatic changes ("Worsening") and "Typical" behaviour however

in the LAST group only. Eleven items had a ratio greater than 0.15 (they were significantly different from 0; uncorrected $p < 0.007$; item 30 remained significant after correction). The first two items described the need for sameness and routine (item 30: 29%, item 63: 24%); two items described "hot" (social) executive functions and literal interpretation of phrases (item 21: 17%, item 27: 17% respectively). The other items (15%–17%) described social retirement (items 47, 69, 72, 74) and coping with being different (item 22). Worsening of symptoms was, on average, checked for 7% of the items in the LAST group (accounting for 8.6% of the total RAADS-R score).

According to DSM-5 algorithm, three criteria were significantly different from the average in the LAST group (before correction): B.2 (need for sameness) was higher $t(44) = 2.6$, $p = 0.014$, $d = 0.8$, whereas B.3 (circumscribed Interests – cognitive style), $t(44) = -3.5$, $p < 0.001$, $d = 1.1$, and B.4 (sensory), $t(44) = -2.4$, $p = 0.22$, $d = -0.7$, were lower. In the HAST group, the "Worsening" response category was used, on average, only for 2% of the items.

There was no correlation between "Worsening" and BMI, $r_s(67) = -0.04$, $p = 0.77$, or age $r_s(67) = 0.06$, $p = 0.63$.

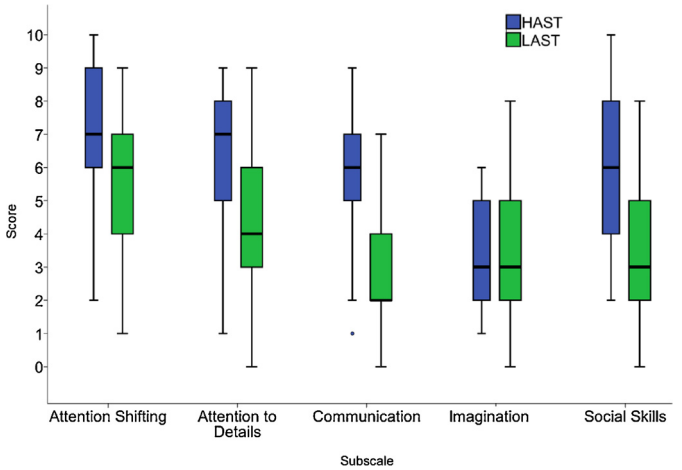

Fig. 3. Boxplot of HAST and LAST Scores on Autism Quotient (AQ) Subscales.
*Difference is significant at the 5% level after Sidak correction ($p < 0.01$).

3.4.3. AQ

The autistic quotient was completed by 41 participants (23 with LAST, 18 with HAST). We found a significant difference in AQ total score $F(1, 39) = 17.7$, $p < 0.001$, $d = 1.36$, communication, $F(1, 39) = 19.7$, $p < 0.001$, $d = 1.46$, and social skills, $F(1, 39) = 12.9$, $p = 0.005$, $d = 1.18$, subscales between HAST and LAST groups. Attention to detail, $F(1, 39) = 7.2$, $p = 0.054$, $d = 0.89$, and attention shifting, $F(1, 39) = 5.0$, $p = 0.151$, $d = 0.73$, showed a trend toward greater values between the groups, but they were not significant after correction. Imagination difficulties were low and similar in both groups, $F(1, 39) = 0.10$, $p = 0.75$, $d = 0.10$ (Fig. 3).

The correlation between the imagination subscale and the other four subscales was low (0.09–0.18) and not significant, whereas social skills, communication and attention shifting were highly correlated together (0.63–0.72) and with the total AQ score (.80–.87).

Using ROC-curve analysis to find the cut-off for HAST, the area under the curve (AUC) was 0.81 (0.07); the highest accuracy was 0.76, corresponding to a cut-off of 29 (sensitivity = 0.61 and specificity = 0.91). We found no significant difference between HAST and LAST for any single item. We did not find any significant correlation between AQ and age, $r_s(41) = -0.12$, $p = 0.47$, or BMI $r_s(41) = -0.05$, $p = 0.74$. AQ was correlated with RAADS-R, $r_s(41) = 0.620$, $p < 0.001$ and RAADS-M $r_s(41) = 0.564$, $p < 0.001$.

3.4.4. EQ

All participants who completed the AQ also completed the EQ. We found no significant correlation between EQ and age, $r_s(41) = 0.11$, $p = 0.51$, or BMI $r_s(41) = 0.03$, $p = 0.86$.

Mean EQ score was lower in HAST participants than in LAST, but only marginally significant $F(1, 39) = 3.5$, $p = 0.07$, $d = 0.61$.

We found no significant difference in EQ for the total for any single item ($p > 0.0013$) between HAST and LAST. EQ was negatively correlated with AQ, $r_s(41) = -0.655$, $p < 0.001$, RAADS-R, $r_s(41) = -.359$, $p = 0.01$, and RAADS-M, $r_s(41) = -0.349$, $p = 0.02$. Ten items had a medium effect size ($0.5 < d < 0.8$) and were significant before correction; they were all related to emotional perspective-taking and nonverbal communication. Sixteen items had a very small effect size ($d < 0.2$), and they were mainly related to empathic concern, prosocial behaviours and self-monitoring during social interaction.

4. Discussion

This study set out to investigate the prevalence of persons with high ASD traits (HAST) in an eating disorder population on their first visit to an ED clinic, using DSM-5 criteria for both conditions. Further, it aimed to validate a clinical tool that assists in discriminating between patients with high and low ASD traits, exploring common and specific autistic traits shared by the two groups, and the changes after ED development.

The prevalence of HAST was 33% in the total sample and was not significantly different between ED categories. The prevalence in narrow AN was 20%, in line with previous studies using self-reports, but we also found a high and comparable prevalence of HAST in other ED. The view of a preferential link between AN and HAST was not supported by this study.

Participants with HAST were younger and age explained 6% of RAADS-M variance. Considering only the total number of endorsed symptoms, the correlation with age was similar, $r_s(67) = -0.23$, $p = 0.06$, to the RAADS-M algorithm, so the results were unlikely to be biased by the scoring difference for present and past symptoms. In the first RAADS-R validation study, Ritvo and colleagues (2011) found sensitivity issues at a young age so we expected a bias in the opposite direction. Therefore, a possible explanation is that the presence of elevated ASD traits increases the general concern about the health status of the

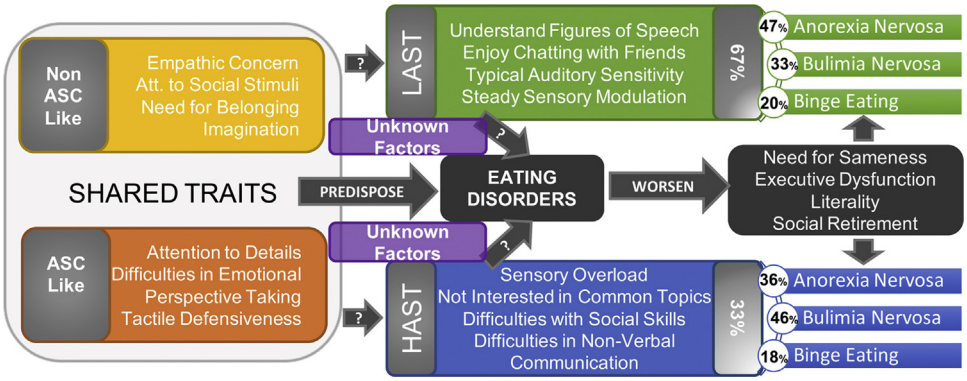

Fig. 4. Specific and Shared Traits Between participants with high (HAST) and low (LAST) autism spectrum traits. Frequency of eating disorder categories: anorexia nervosa (AN), bulimia nervosa (BN) and binge eating disorder (BED).

person, leading to a quicker referral to services. We did not find any specific effects of BMI on autistic traits but we cannot draw any conclusion about the starvation hypothesis because we had few participants with a very low BMI.

The original RAADS-R cut-off led to a low specificity (78%) compared to our clinical judgment and DSM-5 criteria. A cut-off of 106 was the one with the highest (99%) accuracy in our study. The cut-off was higher than the one found in previous studies (65–72) which was probably due to the combined effect of the new DSM-5 diagnostic criteria (Smith, Reichow, & Volkmar, 2015) and an overall shift due to the presence of ED and comorbidities.

Indeed, our modified algorithm (RAADS-M), led to a 100% accuracy with a cut-off of 56 (corresponding to a regressed score of 90 on RAADS-R with an intercept at 10). We mapped RAADS-M items on DSM-5 criteria. The consistency of the new subscale was good and thresholds for each one were found in order to support a DSM-5 diagnostic algorithm (99% accuracy).

The worsening of symptomatology was higher (15%) in the DSM-5 subscale B.2. related to "insistence on sameness" in the LAST group. Domains B.3 and B.4, which related to restricted interests and sensory sensitivity, were the most stable ones ("Worsening" 3–4%). The kind of responses available in RAADS did not allow us to explore the worsening in already relevant traits (for the HAST group). Comorbidities, assessed with SCL-90, affected RAADS-R (explained variance 8.5%) but did not affect the RAADS-M score in a significant way.

In the AQ test, the main differences between the HAST and LAST groups were in the social skills and communication scales, whereas imagination difficulties were low in both groups. The HAST groups also had a lower EQ, but the difference was only marginally significant.

The HAST and LAST groups showed features of two distinct populations as evident from the bimodal shape of RAADS-M distribution, with 50% of participants scoring less than 24 and 33% scoring more than 72, and the very large effect size between the groups.

The results of our study suggest that some traits are shared between different subgroups and they can be either representative of a common phenotype or developed as a consequence of comorbidities and the ED itself. However, other traits are distinctive of a subgroup of patients with ED with an overall high level of ASD traits (Fig. 4), suggesting that different causal theory can explain different traits in different people. The group was too small to run a factor analysis, but a clinical and descriptive clustering of items highlights a propensity to sensory overload, lack of interest in common topics and difficulties with social communication, non-verbal language, proxemics and pragmatics considered to be features of HAST. We also found traits frequently or rarely present in both HAST and LAST groups, suggesting a shared phenotype characterised by attention to detail, difficulties with emotional perspective-taking and tactile defensiveness but intact empathic concern and prosocial behaviour, social motivation and desire for belonging and relationships. Traits associated with an increased need for sameness and routines, social retirement and difficulties with executive functions in social situations worsened after the development of an ED.

5. Implications

Females with mild ASD frequently reach adolescence or adulthood without diagnosis and might be seen in clinics for other conditions, but are not recognised, or assessed in relation to ASD. Characterizing different subgroups according to ASD traits is a way of reducing the high heterogeneity present in ED. Moreover, the acknowledgment of a separable HAST group could prompt further investigation and a better and more comprehensive intervention. Different subgroups could respond differently to different Intervention protocols, for instance, cognitive remediation therapy (Tchanturia, Lounes, & Holttum, 2014) already shown to improve some specific ASD traits in ED but could have different effects in different groups. CBT protocols already adapted to ASD (Spain, Sin, Chalder, Murphy & Happé, 2015) or social skills training on the other hand could be useful for a significant number of patients with HAST independent of the specific ED, whereas other approaches could be beneficial for patients with LAST. Aberrant eating habits could be a cause but also a symptom of the difficulties and cognitive

style found in people with ASD. The high prevalence of HAST in all EDs suggest the importance of studying the common traits underlying different EDs.

5.1. Future directions

Future development could involve the use of RAADS-R in a longitudinal study to measure the evolution of ASD traits before and after the treatment to see if the patients still meet the criteria for ASD and if there is a change in the "worsening" and "improving" category. It could also be important to assess the presence of other neurodevelopmental conditions like Attention Deficit and Hyperactivity Disorder (ADHD) and to model in more detail the mediation effect of other traits or comorbidities (anxiety, depression, Obsessive-Compulsive traits, etc.).

5.2. Conclusions

RAADS-R with our modified algorithm was useful in separating a mixed ED population into two clusters according to the presence of a high or low level of ASD traits. Our modified algorithm showed a high accuracy in classification when compared to clinical judgment and DSM-5 criteria. Moreover, it is easily used for patients from the age of 15, and is not significantly influenced by the worsening of symptoms due to comorbidities. The presence of two distinctive groups, with quantitatively and qualitatively different autistic traits in the ED population suggests that future studies on ED cognitive or behavioural phenotypes should first clinically categorize participants according to the presence of ASD traits in order to study separately the effect of shared traits within the whole ED population, the effects of comorbidities and the presence of a substantial group with probably previously undiagnosed ASD. Both clinicians and cognitive scientists would benefit from disentangling the two groups in order to develop a causal model for eating disorders and to provide adequate and personalised treatment for this population.

Conflict of interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.rasd.2016.10.002.

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