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RESEARCH PAPER

IS ALEXITHYMIA THE LINK BETWEEN ANOREXIA AND AUTISM SPECTRUM DISORDERS?

Mario Miniati, Donatella Marazziti, and Laura Palagini

Abstract

Objective: Alexithymia main features include deficits in empathy, emotion recognition and regulation. Alexithymia has been recently proposed as a potential key to explain the presence of the so-called 'autistic spectrum disorder' signs (ASD), in patients with Anorexia Nervosa (AN). Objective of this review is to summarize current knowledge on the potential role of alexithymia in linking ASD and AN.

Method: A systematic search has been conducted on PUBMED database of the last 10 years, in accordance with PRISMA Guidelines, applying queries in the 'PubMed Advanced Search Builder'.

Results: We initially retrieved 18 papers; the final selection has led to seven papers. According to the available studies, alexithymia is widely represented in samples of AN patients and comorbid ASD traits. However, the specific load of alexithymia in AN with ASD features is still in debate, as well as the potential role of interoceptive deficits. We have found several limitations in the reviewed studies, which shared a cross-sectional design, with no comparison between a pre and a post-treatment condition (except for one study), small samples sizes and some heterogeneity of administered instruments.

Conclusions: the specific load of alexithymia in explaining the link between AN and ASD is still in debate. Interoception deficit has been proposed as having a crucial role. Further research should be devoted to longitudinal studies and not only to cross-sectional observations.

Key words: alexithymia, anorexia nervosa; autism spectrum disorder, interoception

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1. Introduction

Relationships between Anorexia Nervosa (AN) and Autism Spectrum Disorders (ASD) are extensively described in literature. A number of studies documented the presence of autistic traits or symptoms in patients with AN (Huke et al., 2014; Westwood & Tchanturia, 2017). As summarized in a recent review, AN and ASD patients may share similar neuropsychological profiles, socio-emotional difficulties, significant problems with emotion recognition, empathic abilities, emotional introspection, attention switching, and perspective-taking (Boltri & Sapuppo, 2021). Patients with ASD may show rituals around eating and extreme food selectivity, even if there is no fat-phobia or weight concern (Karjalainen et al., 2019; Spek et al., 2019). Moreover, there is an overlap between the two realms in several dimensions of temperament and social functioning (Zhou, McAdam & Donnelly, 2018), considering that both subjects with AN and ASD tend to have pre-morbid patterns of '*interpersonal discomfort*', (Zucker et al., 2007), and enduring severe difficulties in a number of social activities or in making/maintaining close interpersonal relationships (Treasure et al., 2013).

However, these shared characteristics are in contrast with other typical presentations of AN vs. ASD. Anorexia nervosa is characterized by an intense fear or gaining weight, determining low body mass index (BMI), and a persistent influence of weight, shape and body image on self-evaluation; it tends to manifest during childhood or adolescence, with high treatment dropout and relapse rates (Micali et al., 2013). In contrast, autism spectrum disorders (ASD) are neuro-developmental disorders, characterized by marked difficulties with social interaction and communication, and by repetitive, stereotyped interests and behaviors, sometimes complicated by intellectual disability (Loomes et al., 2017). Anorexia Nervosa is still more commonly diagnosed in females, with a typical onset in childhood or adolescence (Micali et al., 2013; Miniati et al., 2016; Ciberti et al., 2020), whereas autism is more frequently diagnosed in males, with an onset during the first year of infancy (Loomes et al., 2017).

A recent line of research investigated the potential role of alexithymia both in AN, and in ASD. Alexithymia is characterized by difficulties in

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identifying and describing feelings (one's own and those of others), and by an externally oriented cognitive style (Mattila et al., 2008). Subjects with alexithymia find difficult to discriminate internal feelings from physical sensations and show marked deficits in empathy, emotion recognition, and regulation (Mattila et al., 2008). Alexithymia is also associated with lower interoceptive accuracy, and it has been hypothesized to be the product of impaired interoception (Brewer, Cook & Bird, 2016).

According to a recent systematic review, approximately 50% of patients with ASD may fulfill the criteria for comorbid alexithymia (Kinnaird, Steward & Tchanturia, 2019). Similarly, alexithymia is a common condition in AN (Tauro et al., 2022).

Recently, it has been hypothesized that a number of '*comorbid ASD features'* in AN patients, such as emotion recognition difficulties or deficit in empathy and interoception, should be more appropriately considered as linked to an underlying *'alexithymia dimension'* rather than to autism traits itself. Evenly, the emotional deficit described by patients with AN could be considered as part of a pre-morbid and enduring alexithymia trait (Adams et al., 2022).

Aim of this review is to summarize current knowledge on the potential role of alexithymia in linking ASD and AN, not exclusively from an heuristic point of view, but in order to clarify, when possible, its clinical and therapeutic implications.

2. Methods

2.1 Protocols and Registration

This review is not included in a research protocol.

2.2 Study Design

The following review was completed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Moher et al., 2009).

2.3. Inclusion and exclusion criteria

The inclusion criteria were defined as follows: (1) scientific articles published in English only and during the last 10 years; (2) articles adopting a phenomenological/clinical perspective; (3) studies examining alexithymia and interoception as potential link between AN and ASD; (4) studies of all age groups; (5) studies exploring the impact of alexithymia on AN-Autism comorbidity treatment; (6) studies using both self-report and diagnostic measures to assess alexithymia in AN with ASD; (7) cross-sectional and longitudinal study designs. Inclusion/exclusion criteria according to PICOS framework, as summarized in **table 1** (Schardt et al., 2007)

Studies published in other languages than English or before May 2012, literature reviews, meta-analyses, case reports, qualitative research designs, were excluded (see **figure 1** for PRISMA diagram) (Moher et al., 2009).

2.4. Information source and Search procedures

A search was conducted in April 2021, on the last 10 years. PubMed database was searched, and the following queries in the *'PubMed Advanced Search Builder'* were applied:

Search 1: ((alexithymia) AND (anorexia)) AND (autism) Filters: in the last 10 years Sort by: Most Recent

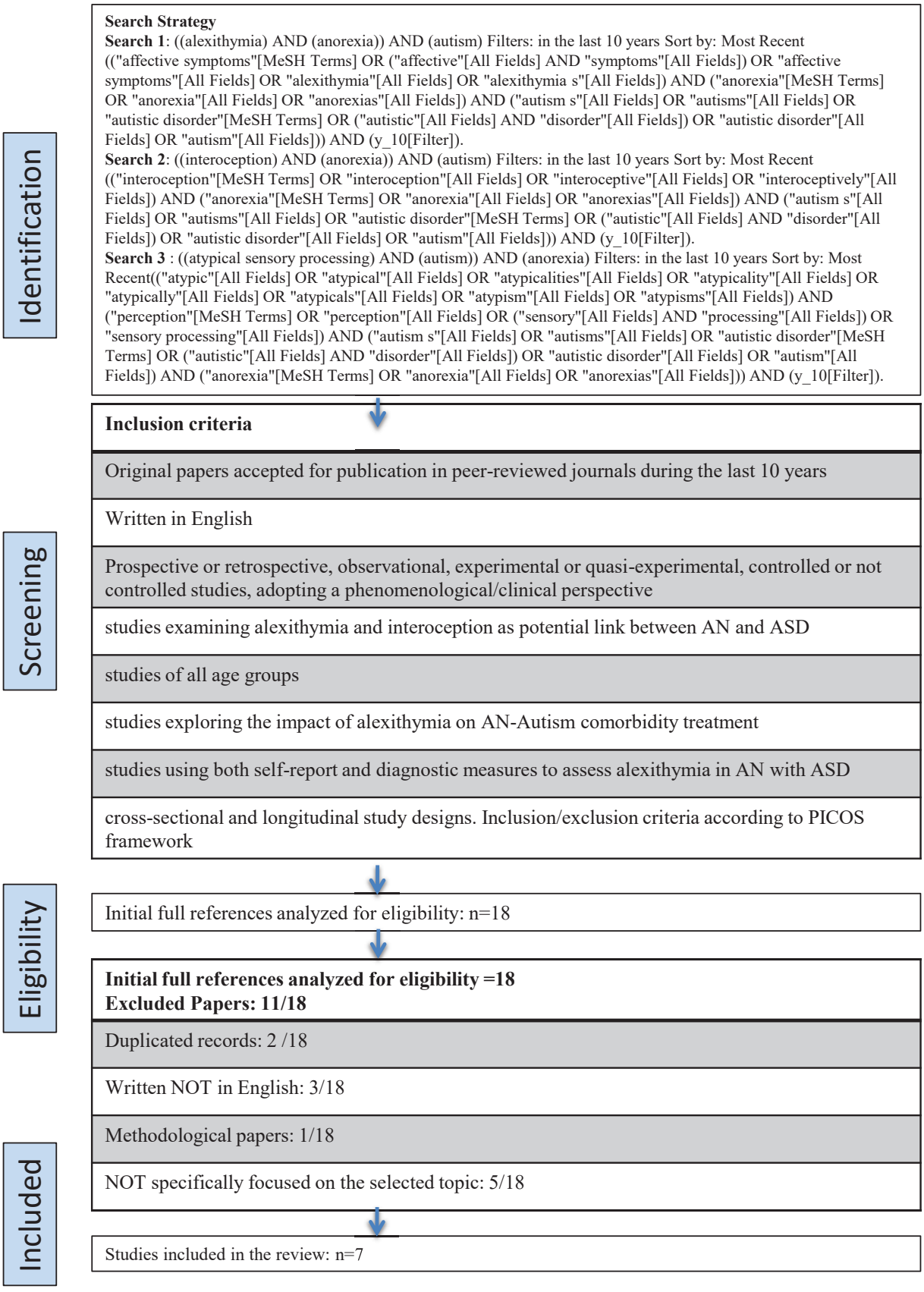
(("affective symptoms"[MeSH Terms] OR ("affective"[All Fields] AND "symptoms"[All Fields]) OR "affective symptoms"[All Fields] OR "alexithymia"[All Fields] OR "alexithymia s"[All Fields]) AND ("anorexia"[MeSH Terms] OR "anorexia"[All Fields] OR "anorexias"[All Fields]) AND ("autism s"[All Fields] OR "autisms"[All Fields] OR "autistic disorder"[MeSH Terms] OR ("autistic"[All Fields] AND "disorder"[All Fields]) OR "autistic disorder"[All Fields] OR "autism"[All Fields])) AND (y_10[Filter]): **11 papers retrieved**.

Search 2: ((interoception) AND (anorexia)) AND

Table 1. *Eligibility criteria (PICOS)*

Systematic review components	Inclusion criteria	Exclusion criteria
Population	All age groups of patients with Anorexia Nervosa (AN), Autism Spectrum disorders (ASD) and Alexithymia.	Subjects with altered eating due to other concomitant conditions, or with no ASD or alexithymia.
Intervention	Face-to-face interventions or Online interventions (i.e., use of electronic, digital or mobile devices to support subjects)	Any type of intervention not focused on AN
Comparison	Patients with AN, ASD and alexithymia traits vs. Healthy Controls (HC)	Not applicable
Outcomes	Primary outcome: studies exploring the impact of alexithymia on AN-Autism comorbidity treatment (individual or group therapies) Secondary outcomes: effects of alexithymia traits on subjects' outcomes (e.g., emotions management; emotions nature and function; emotion expression vs. emotion suppression, etc.).	Not applicable
Study design	Original articles on studies with a longitudinal design; prospective or retrospective, observational (analytical or descriptive), experimental or quasi-experimental, controlled or non-controlled studies; articles accepted for publication in a peer-reviewed journal, written in English.	Reviews and non-original articles (i.e., case reports, editorials, letters to the Editor and book chapters). Paper published not in English

Figure 1. *Overview of selection procedures*



(autism) Filters: in the last 10 years Sort by: Most Recent

((("interoception"[MeSH Terms] OR "interoception"[All Fields] OR "interoceptive"[All Fields] OR "interoceptively"[All Fields]) AND ("anorexia"[MeSH Terms] OR "anorexia"[All Fields] OR "anorexias"[All Fields]) AND ("autism s"[All Fields] OR "autisms"[All Fields] OR "autistic disorder"[MeSH Terms] OR ("autistic"[All Fields] AND "disorder"[All Fields]) OR "autistic disorder"[All Fields] OR "autism"[All Fields])) AND (y_10[Filter]): **4 papers retrieved.**

Search 3: ((atypical sensory processing) AND (autism)) AND (anorexia) Filters: in the last 10 years Sort by: Most Recent

((("atypic"[All Fields] OR "atypical"[All Fields] OR "atypicalities"[All Fields] OR "atypicality"[All Fields] OR "atypically"[All Fields] OR "atypicals"[All Fields] OR "atypism"[All Fields] OR "atypisms"[All Fields]) AND ("perception"[MeSH Terms] OR "perception"[All Fields] OR ("sensory"[All Fields] AND "processing"[All Fields]) OR "sensory processing"[All Fields]) AND ("autism s"[All Fields] OR "autisms"[All Fields] OR "autistic disorder"[MeSH Terms] OR ("autistic"[All Fields] AND "disorder"[All Fields]) OR "autistic disorder"[All Fields] OR "autism"[All Fields]) AND ("anorexia"[MeSH Terms] OR "anorexia"[All Fields] OR "anorexias"[All Fields])) AND (y_10[Filter]): **3 papers retrieved**.

2.5. Study Selection

The authors independently screened the resulting articles for their methodology and appropriateness for inclusion. A consensus discussion was used to resolve the disagreements of reviewers.

2.6. Data Collection Process and Data Items

The independent authors assessed the language suitability and subject matter of each paper and extracted the data reported in **table 2**. The following factors were obtained from the studies when available, with respect to patients setup: a) the number of patients enrolled; b) age of patients; c) gender distribution; d) diagnostic distribution. With respect to intervention, we collected the information on the treatment administered, when available. With respect to outcomes, we decided to extract the prevalence of diagnostic groups, and the number of instruments administered. Then we summarized the main results of each study.

2.7. Risk of Bias in Individual Studies

The risk of bias of individual studies was not performed considering that we found no RCTs and no systematic follow-up studies.

3. Results

3.1. Database search

The database search identified 18 records, of which 11 (61.1%) remained after the removal of duplicates (two papers; 11.1%) (Kinnaird et al., 2020; Adams et al., 2022), the exclusion of three papers in other languages than English (16.6%) (Ruggieri, 2014; Martinez et al., 2014; Kittel-Schneider & Reif, 2020), and the exclusion of two (11.1%) other papers not on topic (Mizen, 2014; Della Longa et al., 2022) Duplicates' removal was performed, taking advantage of the *'Zotero Reference Manager'*. After screening by title and abstracts, at the end of the selection process, seven studies met the eligibility criteria and were included in the review, with the exclusion of four papers (22.2%), because focused on other topics (Krumm et al., 2017; Crespi & Dinsdale., 2019; Saure et al., 2022) or methodological papers (Adams et al., 2022).

Figure 1 illustrates the selection of the studies in a PRISMA flow diagram (Moher et al., 2009).

3.2. Overview of included studies

The seven studies selected are summarized in **table 2**. A meta-analysis could not be performed because of the lack of homogeneity among the resulting studies. Hence, this systematic review is summarized in a narrative synthesis, in chronological order.

3.3. Summary of Evidence

Courty et al. (2013) explored the degree of overlap between AN, ASD and alexithymia traits, in a group of patients with AN (n=15), a group of ASD patients (n=15) and two matched control groups. The main aim of the study was to explore the level of cognitive and affective autistic traits in AN compared to both healthy controls and ASD patients, with a cross-sectional design. Participants completed a battery of self-reports measures, including the Autism-Spectrum Quotient (AQ) (Baron-Cohen et al., 2001), the Bermond-Vorst Alexithymia Questionnaire-B (Deborde et al., 2008), the Empathy Quotient-short (EQ short) and Systemizing Quotient (SQ-Short) (Baron-Cohen & Weelwright, 2004), the Interpersonal Reactivity Index (IRI) (Davis, 1983), the Eating Attitude Test (EAT) (Garner, Olmsted & Polivy, 1983) and the 13-item Beck Depression Inventory (BDI-13) (Beck & Beamesderf, 1974). The AN group was inhomogeneous for diagnostic composition (10 patients were AN binge/purging, and 5 restrictive AN, according to DSM-IV criteria, using a MINI assessment) (Sheehan et al., 1998), but not by gender (14 females and 1 male). Thirteen males and two females constituted both the ASD and its control groups. The WASI-III (Grégoire & Wierzbicki, 2009) was used to rule out intellectual disabilities, only in the ASD group, not in the AN group. No specific inclusion/exclusion criteria were listed. The mean ages of the samples were stackable, namely 28.1±7.5 and 28.1±7.3 years in ASD and ASD controls, as well as in the AN and AN controls (23.9±4.7 vs. 24.0±4.9). Authors did not find differences between the AN, and ASD groups on alexithymia scores. Conversely, both clinical groups were significantly different from their respective control group. They concluded that alexithymia might significantly account for impaired social skills in both disorders. However, high alexithymia scores were not associated with low empathy levels in the AN sample. The two main study limitations were the small samples' size and the questionable choice of an absence of IQ data collection in the AN group.

The Westwood et al study (2017) was performed on a sample of 60 female patients with AN. The main aim of the study was to examine the presence of depression, anxiety, alexithymia and obsessive-compulsive disorder (OCD), comparing AN patients with high, subclinical or no ASD symptoms. A cross-sectional design was used. Inclusion criteria were as follows: (a)

Table 2. *Studies on Alexithymia in patients with Anorexia and Autism Spectrum Disorders*

Author	Pub Year	Patients #	Study Design	DSM Classification	Study Population	Female subjects	Mean age/SD	Number of rating scales	Main Results
Kerr-Gafney et al.	2021	129	Cross-sectional	DSM-5	AN=41 AN-Recovered (REC)=48 HC=40	AN=37/41 (90.2%) REC=47/48 (97.9) HC=38/40 (95%)	AN=26.6±8.5 REC=26.1±8.1 HC=23.9±4.7	Eye-tracking stimulus material + 7 scales	No significant differences in eye-to-mouth viewing ratio between groups. Time spent by AN patients looking at faces negatively correlated with both alexithymia and ASD traits. Time to first fixation to faces significantly correlated with depression, and anxiety symptoms. Reduced attention to faces of AN pts influenced almost exclusively by ASD traits: the longer delay in orienting to the faces was associated with higher levels of anxiety/depression and functional impairment scores.
Vuiller et al.	2020	421	Cross-sectional	DSM-5	First study: 121 subjects from students' population Second study: 300 subjects from students' population	First study: F/M=101/121 (83.4%) Second Study F/M=237/300 (79%)	First study: 24.3±8.4 Second Study: 20.7±5.6	First study: 3 2nd study: 6	Study 1: significant relationship between autistic traits and alexithymia, and between alexithymia and ED (mediation analysis)., Non-significant the direct relationship between autistic traits and ED when controlled for alexithymia; indirect significant effect of alexithymia on the relationship between ASD and ED. Study 2: mediating role of alexithymia between ASD and ED. The mediation effect of alexithymia was partial, contributed to by other factors (e.g., depression and anxiety) in females alone.
Kinnaird et al.	2020	74	Cross-sectional	DSM-5	37 AN pts matched with 37 healthy controls (HC)	All females	HC=26.0±7.1 AN=26.0±8.0	4+Heartbeat Tracking Task	No differences between AN and HC on interoceptive accuracy. No differences between groups regarding interoceptive sensibility. Positive correlation between task performance and confidence ratings in the HC group, but not in AN. No association between interoceptive accuracy, alexithymia and autism within the AN group.
Kerr-Gafney et al.	2020	147	Cross-sectional	DSM-5	HC=46 AN=51 AN-Recovered=50	HC=43/46 AN=47/51 REC=49/50	HC=24.3±4.4 AN=27.5±8.5 REC=26.3±8.0	10	No differences regarding empathy across the three groups. Higher cognitive empathy scores associated with lower levels of alexithymia and ASD, and with higher IQ. In a regression models, higher affective empathy scores correlated with lower levels of alexithymia, and with higher BMI, low anxiety, depression, social anxiety, and ASD.

Table 2. *Continues*

Author	Pub Year	Patients #	Study Design	DSM Classification	Study Population	Female subjects	Mean age/SD	Number of rating scales	Main Results
Adamson et al.	2018	128	Parallel Open	DSM-IV	AN (n=66) pts in 'Individual CREST' (CREST-I) sample vs AN (n=62) pts. in 'Group CREST' (CREST-G)	All females	25.5	3	CREST-I had significant effect of ASD symptoms. Significant reduction in alexithymia scores for CREST-I participants, at endpoint CREST-G improved patients' motivation but did not significantly impact self-reported social anhedonia or alexithymia.
Westwood et al.	2017	60	Cross-sectional	DSM-5	AN (n=60) female pts receiving either inpatient or day-patient treatment, aged between 18-55 ys.	All females	23.8±2.3	6	The presence of elevated ASD symptoms scores was associated with the presence of alexithymia (TAS-20) and obsessive-compulsive symptoms. Alexithymia mediates the relationship between AN and ASD, causing patients with AN to appear 'autistic' as a secondary effect of alexithymia.
Courty et al.	2013	60	Cross-sectional	DSM-IV	AN (n=15) vs. ASD (n=15) vs. Matched Control Groups (15+15)	28 males 32 females	ASD 28.1±7.5 ASD HC 28.1±7.3 AN 23.9±4.7 AN HC 24.0±4.9	6	No differences between AN, and ASD groups on alexithymia scores, Both clinical groups were significantly different from their respective control group on alexithymia. Alexithymia significantly accounted for impaired social skills in both disorders. High alexithymia scores were not associated with low empathy levels in AN.

aged between 18 and 55 years, (b) no diagnosed history of a neurological condition or acquired brain injury, (c) English speaking, (d) female gender and (e) ability and willingness to provide informed written consent to participate. Patients were assessed with the Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2) (Lord et al., 2012), the Eating Disorder Examination Questionnaire (EDE-Q) (Fairburn & Beglin, 1994), the Hospital Anxiety Depression Scale (HADS) (Zigmond & Snaith, 1983; Crawford et al., 2001), the Obsessive-Compulsive Inventory Revised (OCI-R) (Foa et al., 2002), the Wechsler Abbreviated Scale of Intelligence-2nd Edition (WASI-II) (Wechsler, 2011), and the 20-item Toronto Alexithymia Scale (TAS-20) (Bagby, Parker & Taylor, 1994). Fourteen patients (14/60; 23.3%) scored above the ADOS-2 clinical cut-off, indicating the presence of clinical symptoms associated with ASD. Moreover, the presence of elevated ASD symptoms scores was associated with the presence of alexithymia and obsessive-compulsive symptoms. The authors speculated that alexithymia signs and symptoms might mediate the relationship between AN and ASD, causing patients with AN to appear *'autistic'* as a secondary effect of alexithymia. In this study, IQ was systematically assessed in all participants.

Adamson et al. (2018) tested the effectiveness of Cognitive Remediation and Emotional Skills Training (CREST) for patients with AN, autistic symptoms, and alexithymia, comparing 'individual' (Tchanturia et al., 2015) vs. 'group' CREST intervention (Tchanturia, Doris, & Fleming, 2014). The 'Individual CREST' (CREST-I) sample consisted of 66 AN patients and the 'Group CREST' (CREST-G) of 62 AN patients. The CREST-I was based on an eight-session standardized individual therapy, lasting 40 minutes. The CREST-G was a 5-session standardized group therapy, facilitated by one member of the inpatient psychology team and one member of the ward multidisciplinary team. Sessions lasted an hour and ran on a 5-week cycle. The CREST-G faced 5 main topics: 1) the power of positive emotions; 2) the nature and function of emotions; 3) how do we identify emotions; 4) emotion expression vs. emotion suppression; 5) emotions and needs.

Patients were administered with self-report measures at baseline (before the first session) and at the end of the last session in both interventions. They fulfilled the Social Anhedonia Scale (SAS) (Chapman, Chapman, & Raulin, 1976) and the Toronto Alexithymia Scale (TAS-20) (Bagby, Parker, & Taylor, 1994). All patients completed also the Autism-Spectrum Quotient-10 (AQ-10), as part of their admission assessment (Allison, Auyeung, & Baron-Cohen, 2012). AQ-10 scores were recoded according a cut-off, with patients scoring <6 classified as '0' or 'with low autistic symptoms' vs. patients scoring ≥6 classified as '1' (with 'high autistic symptoms') (Allison, Auyeung, & Baron-Cohen, 2012).

No formal inclusion/exclusion criteria were listed, except for the diagnosis of current AN, according to DSM-IV (APA, 2013). The mean age of the overall sample was 25.5 years (range 18-63 years), with a mean duration of illness, taken at the start of the CREST-G, of 7.6±8.3 years, and a mean BMI at the start 14.8±1.4). In the CREST-G, 41 (66%) patients scored <6 on the AQ-10, and 21 (34%) ≥6. In the CREST-I, 45 patients (68%) scored <6, and 21 (32%) ≥6.

The effect of ASD signs and symptoms on alexithymia-TAS-20 (Bagby, Parker, & Taylor, 1994) scores was significant for CREST-G participants: those who scored ≥6 on the AQ-10, scored also significantly higher on alexithymia.

For the CREST-I there was a significant effect of ASD symptoms on both SAS (Chapman, Chapman, & Raulin, 1976) and TAS-20 (Bagby, Parker, & Taylor, 1994) scores: patients who scored ≥6 on AQ-10 also were high on *'social anhedonia'* and alexithymia measures. Interestingly, there was a significant reduction in TAS-20 (Bagby, Parker, & Taylor, 1994) scores for CREST-I participants, when baseline was compared to endpoint, indicating an improvement of this dimension, together with an improvement in confidence. Conversely, CREST-G intervention improved patients' motivation but did not significantly impact self-reported social anhedonia or alexithymia.

Kerr-Gaffney, Harrison and Tchanturia (2020) performed an interesting cross-sectional study comparing a sample of 51 patients with AN, 51 patients who recovered from AN (REC), and 51 healthy controls (HC), recruited through E-MAIL circular or posters in university campuses. Comorbid psychopathological signs and symptoms of ASD, alexithymia, anxiety, depression, and social anxiety traits were assessed. The main aim of the study was to examine cognitive and affective empathy and perception of non-verbal communication in AN patients. The authors hypothesized a deficit in cognitive empathy performances in AN patients, when compared to HC. Moreover, they speculated that AN patients would show lower overall performances in the perception of non-verbal communication. Participants were aged between 18 and 55 years. The only exclusion criteria were a history of brain trauma or of learning disability. HC were screened using the Structured Clinical Interview for DSM-5 Disorders, research version (SCID-5-RV; 14 First et al., 2015); they were enrolled if their body mass index (BMI) was ≥ 19 and ≤ 27. AN and REC were screened using the SCID-5-RV too (First et al., 2015), in order to confirm a current or a past diagnosis of AN. Participants with current diagnosis of AN were enrolled if BMI ≤ 18.5; REC participants were included in study procedures if BMI was ≥19 and ≤27. Moreover, REC patients were required to have maintained a BMI within the above-mentioned range for at least 1 year prior to testing. Participants were assessed using the Wechsler Abbreviated Scale of Intelligence-Second Edition (WASI-II; Wechsler, 2011), the Eating Disorder Examination Questionnaire (EDE-Q) (Fairburn & Beglin, 1994), the Autism Diagnostic Observation Schedule-2nd edition (ADOS-2), Module 4 (Lord et al., 2012), the Social Responsiveness Scale-2nd Edition, Adult Self-report form (SRS-2) (Constantino & Gruber, 2005), the Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983), the Liebowitz Social Anxiety Scale (LSAS) (Liebowitz, 1987), the Twenty-item Toronto Alexithymia Scale (TAS-20) (Bagby, Parker, & Taylor, 1994), the Work and Social Adjustment Scale (WSAS) (Mundt et al., 2002), the Multifaceted Empathy Test (MET) (Dziobek et al., 2008), and the Mini-Profile of Nonverbal Sensitivity (MiniPONS) (Bänziger et al., 2011). The MiniPONS measures 3 different abilities, namely ability to recognize emotions, interpersonal attitudes and intentions, through four different modes of non-verbal communications. Forty-six HC, 51 AN, and 50 REC participants were included in the final sample; five HC were excluded because of their EDE-Q scores, and one REC had a BMI>27. Groups were all of similar age, gender, and IQ. Patients with AN showed the highest levels of alexithymia. Surprisingly, no differences were found regarding empathy across the three groups. A possible explanation was that the self-reporting one's own empathic abilities might be misleading in a sample with high levels of alexithymia, as was the case of the

AN group of this study. Correlation analyses showed how higher cognitive empathy scores were associated with lower levels of alexithymia and ASD symptoms, measured by both the ADOS-2 (Lord et al., 2012) and SRS-2 (Constantino & Gruber, 2005), and with higher IQ, especially in the oldest subjects. However, when entered into regression models, higher affective empathy scores were correlated not only with lower levels of alexithymia, but also with a number of different variables, namely higher BMI, low anxiety, depression, social anxiety, and ASD symptoms. Two main limitations of the study reduced the generalizability of results: the cross-sectional design and the assessment of ASD symptoms with no instruments able to provide an ASD diagnosis.

In the same year, Kinnaird, Stewart & Tchanturia (2020) postulated a key role of interoception in linking alexithymia and autistic traits in AN patients. They were interested in measuring the interoceptive accuracy and sensitivity, using the heartbeat-tracking task, in across-sectional study. A group of 37 AN patients were matched with 37 healthy controls (HC). The main hypothesis of the study was that AN patients would exhibit low levels of interoceptive accuracy and sensitivity if compared to HC. Moreover, they hypothesized that such altered levels of interoceptive accuracy and sensitivity could be related to the presence of alexithymia and/or autistic traits, in patients with AN. Participants were screened with the Structured Clinical Interview for DSM (SCID-5) (First et al., 2015). Exclusion criteria were a history of a neurological disorder or of a severe medical condition. Participants with AN were included only if they had a previous diagnosis of autism. Healthy control (HC) were matched for age and gender and recruited through local universities and online advertising. They were not included if reported a history of ED or other psychiatric disorders, including autism, or if they had a neurological or a severe medical condition. Interoceptive accuracy was assessed using the heartbeat-tracking task. Participants were asked to silently count their heartbeats during 4 randomized time windows (25, 35, 45, and 100 s), and to report the number of counted heartbeats to their researcher, at the end of each window. Interoceptive sensibility was assessed using total scores on the Awareness Subscale of the Porges Body Perception Questionnaire (BPQ) (higher score indicating higher interoceptive sensibility) (Porges, 1993). Alexithymia was measured using the Toronto Alexithymia Scale (TAS-20) (Bagby, Parker, & Taylor, 1994). Autistic traits were measured using the Autism Spectrum Quotient (AQ) (Baron-Cohen et al., 2001). Concurrent anxiety and depressive symptoms were measured using the Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983). Enrolled subjects were all females with the same age (26.05±7.13 for HC vs. 26.08±8.05 for AN). Obviously, BMI was significantly lower in AN patients than in HC (15.8±1.2 vs. 22.8±4.4). The AN group was mainly constituted by restrictive patients (n=31; 83.78%), while only 6 participants had binge/purge AN (16.22%). Interestingly, twenty-nine AN patients were receiving treatment (78.3%), 24 of which (64.86%) taking psychotropic medications.

The study found mixed results. No significant differences were found between AN, and HC on interoceptive accuracy on the overall heartbeat tracking score and at any time point. There were no differences between groups regarding interoceptive sensibility measured with the BPQ (Porges, 1993), but AN patients described a lower self-confidence in their interoceptive task performances. A positive correlation emerged between task performance and confidence ratings in the HC group, but not in the AN group, suggesting that people with AN might have a low insight into their interoceptive abilities. Finally, no association between interoceptive accuracy, alexithymia and autism within the AN group was found. The authors speculated that interoceptive accuracy might be not linked to alexithymia and autistic traits in their sample of AN patients, because of the confounding effect of concomitant variables, such as treatment duration, treatment type or BMI.

Vuiller et al. (2020) published in the same paper results from two cross-sectional studies focused on relationships between alexithymia, autistic traits, and eating psychopathology.

The first study was conducted on a non-clinical sample of 121 participants from a student population (n = 101 females, mean age = 24.3±8.4; age range = 18-64 years old). No inclusion/exclusion criteria were listed, not even on the basis of a current psychiatric diagnosis. As a consequence, the sample was heterogeneous, considering that 52 (43%) subjects reported at least a psychiatric disorder, namely depression (n=11), anxiety (n=15), depression and anxiety (n=21), Obsessive-Compulsive Disorder (OCD) (n=3), Post-Traumatic Stress Disorder (PTSD) (n=2), personality disorders (n=4), psychosis (n=1), Attention Deficit Disorder with Hyperactivity (ADHD) (n=1), autism spectrum disorder (ASD) (n=2), and ED (n=6; no overlap with the two subjects with ASD). Participants were asked to complete on an online platform (Qualtrics) three questionnaires, namely the Autism-Spectrum Quotient (AQ) (Baron-Cohen et al., 2001), the Toronto Alexithymia Scale (TAS-20) (Bagby, Parker, & Taylor, 1994), and the Eating Attitude Test (EAT-26) (Garner, Bohr & Garfinkel, 1982).

The authors performed a mediation analysis, utilizing the bootstrapping method from the SPSS PROCESS macro (Hayes & Preacher, 2014). They analyzed relationships between variables according to the PROCESS Model 4, where autistic traits (X) would exert an influence on eating disorder symptomatology (Y) via the intervening, mediator variable of alexithymia (M). As a main result, they found a significant relationship between autistic traits and alexithymia (path a), and between alexithymia and eating psychopathology (path b). Moreover, when controlling for the presence of alexithymia, the direct relationship between autistic traits and eating psychopathology (path c) became non-significant; conversely, the indirect effect of alexithymia on the relationship between autistic traits and eating psychopathology was significant. Alexithymia accounted for 18% of the effect of autistic traits on eating signs and symptoms. The complete disappearance of the significant relationship between autistic traits and eating psychopathology, upon controlling for TAS-20 scores, suggested a full mediation effect, namely that the aforementioned relationship was dependent on the presence of alexithymia.

The second study was conducted on a new sample of 300 subjects (237 females, mean age 20.7±5.6; age range = 18-60 years) still recruited from a student population. Again, no exclusion/inclusion criteria were listed, and 95/300 subjects declared their psychiatric diagnoses, including depression (n=21), anxiety (n=30), combined depression and anxiety (n=29), OCD (n=6), PTSD (n=2), ADHD (n=2), personality disorder (n=2), and psychosis (n=1). Moreover, 17 subjects reported a diagnosis of an Eating Disorder (n=9 AN; n=5 BN, n=2; n=1 Eating Disorder not Otherwise Specified, ED-NOS). Four participants had an autism spectrum

diagnosis and three of them had a comorbid eating disorder (BN, AN, and Binge-Eating Disorder, BED).

As in the first study, participants completed the TAS-20 (Bagby, Parker, & Taylor, 1994), the AQ (Baron-Cohen et al., 2001), and the EAT-26 (Garner, Bohr & Garfinkel, 1982) together with three additional measures, namely the Levels of Emotional Awareness Scale, short form (B) (LEAS) (Lane et al., 1990), the Patient Health Questionnaire (PHQ-9) (Kroenke, Spitzer & Williams, 2001) and the Beck Anxiety Inventory (BAI) (Beck & steer, 1990).

Preliminary analyses on questionnaires cut-off scores revealed that participants were below the diagnostic thresholds for full-blown current ASD, ED, or alexithymia.

The mediation analysis on AQ (Baron-Cohen et al., 2001), TAS-20 (Bagby, Parker, & Taylor, 1994), and EAT-26 (Garner, Bohr & Garfinkel, 1982) total scores showed a significant relationship between autistic traits and alexithymia, and between alexithymia and eating signs/symptoms.

Female gender had no significant effect on the relationship between autistic traits and alexithymia but showed a significant effect on the model predicting ED.

More in detail, gender moderated the relationship between autistic traits and ED, showing a partial mediation exclusively in female subjects with a significant direct effect of autistic traits on ED, and a significant indirect effect via alexithymia (TAS-20) (Bagby, Parker, & Taylor, 1994) scores. When anxiety and depression symptoms entered the model (via BAI and PHQ scores) (Beck & steer, 1990; Kroenke, Spitzer & Williams, 2001) they significantly contributed, along with one of the three TAS-20 (Bagby, Parker, & Taylor, 1994) factors, namely the 'difficulty identifying feelings' (DIF) factor. The two other TAS-20 (Bagby, Parker, & Taylor, 1994) factors, the 'difficulty describing feelings-DDF, and the inclination away from introspection and towards externally orientated thinking-EOT) were less relevant.

The analyses on the Levels of Emotional Awareness Scale, short form (B) (LEAS) (Lane et al., 1990) as mediator revealed that the overall model predicting LEAS scores (Lane et al., 1990) was marginally significant, and that the relationship between autistic traits and LEAS (Lane et al., 1990) scores was not. Moreover, the relationships between the LEAS (Lane et al., 1990) and the TAS-20 (Bagby, Parker, & Taylor, 1994) were all below significance.

In summary, the first study concluded that autistic traits might exert their influence on eating psychopathology not directly, but indirectly, via alexithymia. The second study revealed that alexithymia had a mediating role (in particular, the difficulty in identifying feelings-DIF subscale of TAS-20) (Bagby, Parker, & Taylor, 1994) in the relationships between ASD and ED. However, the mediation effect of alexithymia was partial, contributed to by other factors (including, depression and anxiety), in females alone.

The last study we found (Kerr-Gafney et al., 2021) was focused on the presence of autistic traits that might negatively affect social attention in a sample of AN patients vs. AN patients who recovered (AN-REC), and healthy controls (HC). In this study, alexithymia was considered as a potential factor altering the socio-cognitive processes of AN patients, together with high levels of depression and anxiety.

Participants were required to be ≥18 and ≤55 years old. The only exclusion criteria were a history of brain trauma or learning disability. HCs were recruited through circular emails and posters around campuses; they were screened using the Structured Clinical Interview for DSM-5 Disorders, research version (SCID-5-RV; First et al. 2015), and required to have a BMI between 19 and 27, as well as AN-REC patients. Conversely, AN patients were required to have a BMI ≤ 18.5. All participants were administered with a eye-tracking stimulus material, namely a movie clip from the Dynamic Images and Eye Movements database (*'Fifty People One Question: Brooklyn'*) (https://thediemproject. wordpress.com/) (Vo et al., 2012) . Their eye movements were recorded using a Tobii TX300 eye-tracker. After eye tracking, participants were administered with the Wechsler Abbreviated Scale of Intelligence-Second Edition (WASI-II; Wechsler 2011) to measure IQ. Then, they fulfilled six self-report questionnaires: the Eating Disorder Examination Questionnaire (EDE-Q) (Fairburn & Beglin 1994), the Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith 1983), the Liebowitz Social Anxiety Scale (LSAS) (Liebowitz 1987), the Twenty-item Toronto Alexithymia Scale (TAS20) (Bagby, Parker, & Taylor, 1994), the Social Responsiveness Scale-2nd Edition, adult self-report form (SRS-2) (Constantino & Gruber 2012), and the Work and Social Adjustment Scale (WSAS) (Mundt et al. 2002).

A total of 129 subjects completed the overall tasks, namely 41 AN patients, 48 AN-REC, and 40 HCs. They were all of similar mean age, and with a preponderance of female gender (90.2% in AN sample, 97.9% in AN-REC, and 95% in HCs).

Like in the Vuiller et al (2020) study, the SPSS macro PROCESS was used to perform a set of mediation analyses (Hayes & Preacher, 2014).

A first group of analyses was performed in order to evaluate differences between groups in attention to faces and attention to facial features. AN patients looked at faces significantly less, even if there were no significant differences between the three groups regarding time to first fixation, suggesting that there was a reduced attention to faces in the acute state of AN, but AN may show initial interest in orienting to social stimuli, and might disengage from such stimuli more quickly than HCs

Moreover, there were no significant differences in eye-to-mouth viewing ratio between the three groups. The time spent by AN patients looking at faces was negatively correlated with both alexithymia traits (TAS-20 scores) (Bagby, Parker, & Taylor, 1994) and ASD traits (SRS-2 scores) (Constantino & Gruber 2012), while time to first fixation to faces was significantly positively correlated with WSAS, (depression), and anxiety scores (Mundt et al. 2002). However, with a hierarchical regression model, the addition of SRS-2 scores led to a significant increase; conversely, the addition of TAS-20 (Bagby, Parker, & Taylor, 1994) scores did not, and in a final model, only SRS-2 (Constantino & Gruber 2012) scores made a significant unique contribution to explaining the variance in time spent looking at faces. This finding suggested that only ASD symptoms predicted looking duration to faces.

However, the ASD traits were measured with the SRS-2 (Constantino & Gruber 2012) that might be are influenced by symptoms of anxiety, depression, or even alexithymia

A second set of analyses was performed to explore the potential relationships between social attention levels and psychopathological features, assessed with the EDE-Q (Fairburn & Beglin 1994), HADS anxiety, HADS depression (Zigmond & Snaith 1983), TAS-20 (Bagby, Parker, & Taylor, 1994), LSAS, SRS-2 (Constantino & Gruber 2012), and WSAS (Mundt

et al. 2002). In summary, the authors confirmed that the reduced attention to faces of AN patients resulted significantly influenced almost exclusively by ASD traits, even if a longer delay in orienting to the faces was significantly associated with higher levels of anxiety/depression (HADS scores) (Zigmond & Snaith 1983) and functional impairment (WSAS scores) (Mundt et al. 2002) .

4. Discussion

The true significance of autistic traits in AN, despite and above their detection with a number of different instruments is in debate (Pooni et al., 2012). The question if inflexibility and impairments in social cognitions of AN patients are '*truly autistic*' or not is still unanswered. Contemporary models of AN emphasize interpersonal difficulties as key factors for AN development and maintenance (Miniati et al., 2018). Patients with AN are often characterized by high levels of social anhedonia and anxiety, that might be present not only during the acute phase of the disorder, but also before its full-blown presentation and after recovery, in remission phases (Kerr-Gaffney et al., 2020). AN patients describe a subjective sense of poor social skills, and tend to have less social problem-solving strategies when compared to general population (HCs) (Rhind et al. 2014; Sternheim et al. 2012). Also for these reason, CBT and Interpersonal Therapy are still considered in a number of studies, as first choice treatments for AN (Franko et al. 2013; Miniati et al., 2018).

The new line of research hypothesizing that alexithymia, with its interoceptive deficits, could be '*the underlying dimension*' linking AN and ASD, especially when a general deficit in interoception is considered, is intriguing. However, this hypothesis still needs to be confirmed. Results from our systematic review suggest that overall available finding is mixed. We retrieved a total of seven studies published in the last decade. The studies we selected were heterogeneous mainly for the procedures, in part for measures, leading to inhomogeneous results. However, we found at least three relevant issues, as summarized below:

Alexithymia is commonly detected in samples of AN patients and comorbid ASD traits, but the specific role of alexithymia in AN with ASD features is unclear. In a study alexithymia accounted for impaired social skills but not for low empathy levels in AN (Courty et al., 2013). In two other studies, elevated ASD symptoms scores in AN patients were associated not exclusively with the presence of alexithymia, but also with obsessive-compulsive spectrum symptoms (Westwood et al. 2017), or jointly with a number of other clinical and socio-demographic variables (namely, BMI, anxiety, depression, social anxiety) (Kerr-Gaffney et al., 2020). In a study more focused on interoception, no association between interoceptive accuracy, alexithymia and autism within the AN group was found, maybe because of the confounding effect of other concomitant variables, such as treatment duration, treatment type or BMI (Kinnaird et al., 2020). Again, in first of the two elegant Vuillier studies (2020), alexithymia was found to be the pathway of autistic traits trough AN. However, the second study on a wider sample partially confirmed the mediating role of alexithymia in the relationships between ASD and AN, limiting its impact only on female gender and together with other clinical variables, such as depression and anxiety.

Interoception deficit might be the common problem underlying the three disorders. Several observations suggest that atypical interoception might have a crucial role not only in Alexithymia but also in the etiology of both ASD (DuBois et al., 2016; Garfinkel et al., 2016) and ED (Herbert et al., 2020). However, this hypothesis, repurposed in a recent methodological paper by Adams et al. (2022), has been systematically investigated only in one study (Kinnaird et al., 2020), with small sample size and mixed results, as already summarized. We believe that further research is needed in this field, with the aim to explore if interoceptive deficits due to alexithymia in AN patients (especially when ASD traits are present) might explain the heightened emotional arousal and the difficulties in managing sensations associated with emotion detection.

The relevance of a *'dimensional'* approach to patients with AN, not only to patients with ASD. Taken as a whole, finding from the reviewed papers highlighted the importance of referring to different diagnostic construct, such as Alexithymia, Anorexia or Autism in a dimensional manner, assessing, along a *continuum*, psychological and psychopathological characteristics, in a trans-diagnostic perspective. Studies in this systematic review are all with AN samples recruited on the basis of DSM-IV or DSM-5 diagnostic criteria. Obviously, the procedure is methodological correct, in order to collect homogeneous samples. However, almost all studies had a cross-sectional design, raising more than a question, considering the instability over time of anorexia and bulimia diagnoses, the frequent crossover between the two, and the sharing of most characteristics, irrespective of DSM diagnoses (Milos et al., 2005; Miniati et al., 2017; Miniati et al., 2018). Under this point of view, the effort of the reviewed studies to describe psychological and psychopathological dimensions over diagnostic categories is considerable. The attempt to identify potential common pathways linking AN, ASD and alexithymia in a dimensional perspective might be the most promising approach to the definition of more refined clinical phenotypes for AN patients.

5. Summary of limitations

The results of this review must be interpreted with caution due to seven main limitations: 1) retrieved studies had exclusively a cross-sectional design; 2) only one study compared a pre-treatment vs. a post-treatment condition (Adamson et al., 2018); in the remaining studies, no treatment implications were considered; 3) studies varied in terms of populations sampled; 4) no studies accounted for attrition rates; 5) except for two studies on general population (Vuiller et al., 2020) samples size is limited; 6) No studies with follow-up data were available; 7) studies varied in terms of instruments administered, except for alexithymia assessment. When different instruments are used, there is always the question on how to compare findings from scales exploring in different ways psychological and psychopathological areas such as AN, and ASD. However, this heterogeneity reflects the effort to explore a number of psychological and psychopathological variables, including depressive, anxiety, and obsessive traits other than AN, ASD and alexithymia traits, in a dimensional rather than a categorical way.

6. Conclusions and clinical implication points

We are aware of the addressed limitations of current knowledge on alexithymia as possible element linking AN, and ASD. However, despite the above-mentioned weaknesses in a number of areas, it is clear that the

evidence base is intriguing. In order to achieve a deeper knowledge in this field, we suggest the following recommendations for future research:

- Further efforts should be devoted to longitudinal studies and not only on cross-sectional observations.
- Randomized clinical trials should be carried out to evaluate how to treat patients with AN, alexithymia and ASD signs and symptoms.
- Further studies are needed to clarify the potential role of interoception in linking Anorexia Nervosa and ASD.
- Finally, we believe that the *continuum* between the two psychopathological realms of AN, and ASD could benefit of an integrated approach, combining the dimensional and the categorical view of the disorders. Such integrated approach to psychopathology should consider as clinically relevant not only threshold-level manifestations, but also atypical symptoms, behavioral traits and temperamental features.

Authorship

All authors gave their substantial contributions to conception and design, data acquisition, data analysis and interpretation. All authors gave contributions in drafting the article or critically revising it for important intellectual content and gave their final approval of the version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of the work are appropriately investigated and resolved.

References

Adams, K. L., Murphy, J., Catmur, C., & Bird, G. (2022). The role of interoception in the overlap between eating disorders and autism: Methodological considerations. *European Eating Disorders Review: The Journal of the Eating Disorders Association*. https://doi.org/10.1002/erv.2905

Adamson, J., Leppanen, J., Murin, M., & Tchanturia, K. (2018). Effectiveness of emotional skills training for patients with anorexia nervosa with autistic symptoms in group and individual format. *European Eating Disorders Review: The Journal of the Eating Disorders Association*, *26*(4), 367–375. https://doi.org/10.1002/erv.2594

Allison, C., Auyeung, B., & Baron-Cohen, S. (2012). Toward brief "Red Flags" for autism screening: The Short Autism Spectrum Quotient and the Short Quantitative Checklist for Autism in toddlers in 1,000 cases and 3,000 controls [corrected]. *Journal of the American Academy of Child and Adolescent Psychiatry*, *51*(2), 202-212.e7. https://doi.org/10.1016/j.jaac.2011.11.003

APA - The Structured Clinical Interview for DSM-5®. (n.d.-a). Retrieved April 25, 2022, from https://www.appi.org/products/structured-clinical-interview-for-dsm-5-scid-5

Bagby, R. M., Parker, J. D., & Taylor, G. J. (1994). The twenty-item Toronto Alexithymia Scale—I. Item selection and cross-validation of the factor structure. *Journal of Psychosomatic Research*, *38*(1), 23–32. https://doi.org/10.1016/0022-3999(94)90005-1

Bänziger, T., Scherer, K., Hall, J., & Rosenthal, R. (2011). Introducing the MiniPONS: A short multichannel version of the Profile of Nonverbal Sensitivity (PONS). *Journal of Nonverbal Behavior*, *35*, 189–204. https://doi.org/10.1007/s10919-011-0108-3

Baron-Cohen, S., & Wheelwright, S. (2004). The empathy quotient: An investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders*, *34*(2), 163–175. https://doi.org/10.1023/b:jadd.0000022607.19833.00

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5–17. https://doi.org/10.1023/a:1005653411471

Beck, A. T., & Beamesderfer, A. (1974). Assessment of depression: The depression inventory. *Modern Problems of Pharmacopsychiatry*, *7*(0), 151–169. https://doi.org/10.1159/000395074

Boltri, M., & Sapuppo, W. (2021). Anorexia Nervosa and Autism Spectrum Disorder: A Systematic Review. *Psychiatry Research*, *306*, 114271. https://doi.org/10.1016/j.psychres.2021.114271

Brewer, R., Cook, R., & Bird, G. (2016). Alexithymia: A general deficit of interoception. *Royal Society Open Science*, *3*(10), 150664. https://doi.org/10.1098/rsos.150664

Bruni, T. P. (2014). Test Review: Constantino, J. N., & Gruber, C. P. (2012). "Social Responsiveness Scale-Second Edition" ("SRS-2"). Torrance, CA: Western Psychological Services. *Journal of Psychoeducational Assessment*, *32*(4), 365–369. https://doi.org/10.1177/0734282913517525

Chapman, L. J., Chapman, J. P., & Raulin, M. L. (1976). Scales for physical and social anhedonia. *Journal of Abnormal Psychology*, *85*(4), 374–382. https://doi.org/10.1037//0021-843x.85.4.374

Courty, A., Maria, A. S., Lalanne, C., Ringuenet, D., Vindreau, C., Chevallier, C., Pouga, L., Pinabel, F., Philippe, A., Adrien, J.-L., Barry, C., & Berthoz, S. (2013). Levels of autistic traits in anorexia nervosa: A comparative psychometric study. *BMC Psychiatry*, *13*, 222. https://doi.org/10.1186/1471-244X-13-222

Crawford, J. R., Henry, J. D., Crombie, C., & Taylor, E. P. (2001). Normative data for the HADS from a large non-clinical sample. *The British Journal of Clinical Psychology*, *40*(Pt 4), 429–434.

Constantino, J.N., & Gruber, C.P. (2012). Social Responsiveness Scale, Second Edition (SRS-2). Torrance, CA: Western Psychological Services.

Crespi, B., & Dinsdale, N. (2019). Autism and psychosis as diametrical disorders of embodiment. *Evolution, Medicine, and Public Health*, *2019*(1), 121–138. https://doi.org/10.1093/emph/eoz021

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*(1), 113–126. https://doi.org/10.1037/0022-3514.44.1.113

Deborde, A.-S., Berthoz, S., Wallier, J. M., Fermanian, J., Falissard, B., Jeammet, P., & Corcos, M. (2008). The Bermond-Vorst Alexithymia Questionnaire cutoff scores: A study in eating-disordered and control subjects. *Psychopathology*, *41*(1), 43–49. https://doi.org/10.1159/000109955

DuBois, D., Ameis, S. H., Lai, M.-C., Casanova, M. F., & Desarkar, P. (2016). Interoception in Autism Spectrum Disorder: A review. *International Journal of Developmental Neuroscience: The Official Journal of the International Society for Developmental Neuroscience*, *52*, 104–111. https://doi.org/10.1016/j.ijdevneu.2016.05.001

Dziobek, I., Rogers, K., Fleck, S., Bahnemann, M., Heekeren, H. R., Wolf, O. T., & Convit, A. (2008). Dissociation of cognitive and emotional empathy in adults with Asperger syndrome using the Multifaceted Empathy Test (MET). *Journal of Autism and Developmental Disorders*, *38*(3), 464–473. https://doi.org/10.1007/s10803-007-0486-x

Fairburn, C. G., & Beglin, S. J. (1994). Assessment of eating disorders: Interview or self-report questionnaire? *The International Journal of Eating Disorders*, *16*(4), 363–370.

Foa, E. B., Huppert, J. D., Leiberg, S., Langner, R., Kichic, R., Hajcak, G., & Salkovskis, P. M. (2002). The Obsessive-Compulsive Inventory: Development and validation of a short version. *Psychological Assessment*, *14*(4), 485–496.

Franko, D. L., & Striegel-Moore, R. H. (2002). The role of body dissatisfaction as a risk factor for depression in adolescent girls: Are the differences Black and White? *Journal of Psychosomatic Research*, *53*(5), 975–983.

Garfinkel, S. N., Tiley, C., O'Keeffe, S., Harrison, N. A., Seth, A. K., & Critchley, H. D. (2016). Discrepancies between dimensions of interoception in autism: Implications for emotion and anxiety. *Biological Psychology*, *114*, 117–126. https://doi.org/10.1016/j.biopsycho.2015.12.003

Garner, D. M., Olmstead, M. P., & Polivy, J. (1983). Development and validation of a multidimensional eating disorder inventory for anorexia nervosa and bulimia. *International Journal of Eating Disorders*, *2*(2), 15–34. https://doi.org/10.1002/1098-108X(198321)2:2<15::AID-EAT2260020203>3.0.CO;2-6

Garner, D. M., Olmsted, M. P., Bohr, Y., & Garfinkel, P. E. (1982). The eating attitudes test: Psychometric features and clinical correlates. *Psychological Medicine*, *12*(4), 871–878. https://doi.org/10.1017/s0033291700049163

Grant, M. M. (2011). Beck Anxiety Inventory. In S. Goldstein & J. A. Naglieri (Eds.), *Encyclopedia of Child Behavior and Development* (pp. 215–217). Springer US. https://doi.org/10.1007/978-0-387-79061-9_3159

Hayes, A. F., & Preacher, K. J. (2014). Statistical mediation analysis with a multicategorical independent variable. *The British Journal of Mathematical and Statistical Psychology*, *67*(3), 451–470. https://doi.org/10.1111/bmsp.12028

Herbert, B. M. (2020). Interoception and its role for eating, obesity, and eating disorders: Empirical findings and conceptual conclusions. *European Journal of Health Psychology*, *27*(4), 188–205. https://doi.org/10.1027/2512-8442/a000062

Huke, V., Turk, J., Saeidi, S., Kent, A., & Morgan, J. F. (2014). The clinical implications of high levels of autism spectrum disorder features in anorexia nervosa: A pilot study. *European Eating Disorders Review: The Journal of the Eating Disorders Association*, *22*(2), 116–121. https://doi.org/10.1002/erv.2269

Karjalainen, L., Råstam, M., Paulson-Karlsson, G., & Wentz, E. (2019). Do autism spectrum disorder and anorexia nervosa have some eating disturbances in common? *European Child & Adolescent Psychiatry*, *28*(1), 69–78. https://doi.org/10.1007/s00787-018-1188-y

Kerr-Gaffney, J., Harrison, A., & Tchanturia, K. (2020). Autism spectrum disorder traits are associated with empathic abilities in adults with anorexia nervosa. *Journal of Affective Disorders*, *266*, 273–281. https://doi.org/10.1016/j.jad.2020.01.169

Kerr-Gaffney, J., Mason, L., Jones, E., Hayward, H., Harrison, A., Murphy, D., & Tchanturia, K. (2021). Autistic Traits Mediate Reductions in Social Attention in Adults with Anorexia Nervosa. *Journal of Autism and Developmental Disorders*, *51*(6), 2077–2090. https://doi.org/10.1007/s10803-020-04686-y

Kinnaird, E., Stewart, C., & Tchanturia, K. (2019). Investigating alexithymia in autism: A systematic review and meta-analysis. *European Psychiatry: The Journal of the Association of European Psychiatrists*, *55*, 80–89. https://doi.org/10.1016/j.eurpsy.2018.09.004

Kinnaird, E., Stewart, C., & Tchanturia, K. (2020). Interoception in Anorexia Nervosa: Exploring Associations With Alexithymia and Autistic Traits. *Frontiers in Psychiatry*, *11*, 64. https://doi.org/10.3389/fpsyt.2020.00064

Kittel-Schneider, S., & Reif, A. (2020). [Adult attention deficit hyperactivity disorder and comorbidity: New findings on epidemiological and genetic factors]. *Der Nervenarzt*, *91*(7), 575–582. https://doi.org/10.1007/s00115-020-00900-5

Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2001). The PHQ-9. *Journal of General Internal Medicine*, *16*(9), 606–613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

Krumm, A., Ferraro, F. R., & Ingvalson, B. (2017). Exploring the Relationship Between Autistic Traits and Body Image, Body Satisfaction, and Body Competence. *The Journal of Psychology*, *151*(6), 566–579. https://doi.org/10.1080/00223980.2017.1372343

Lane, R. D., Quinlan, D. M., Schwartz, G. E., Walker, P. A., & Zeitlin, S. B. (1990). The Levels of Emotional Awareness Scale: A cognitive-developmental measure of emotion. *Journal of Personality Assessment*, *55*(1–2), 124–134. https://doi.org/10.1080/00223891.1990.9674052

Liebowitz, M. R. (1987). Social phobia. *Modern Problems of Pharmacopsychiatry*, *22*, 141–173. https://doi.org/10.1159/000414022

Loomes, R., Hull, L., & Mandy, W. P. L. (2017). What Is the Male-to-Female Ratio in Autism Spectrum Disorder? A Systematic Review and Meta-Analysis. *Journal of the American Academy of Child and Adolescent Psychiatry*, *56*(6), 466–474. https://doi.org/10.1016/j.jaac.2017.03.013

Martinez, G., Cook-Darzens, S., Chaste, P., Mouren, M.-C., & Doyen, C. (2014). [Anorexia nervosa in the light of neurocognitive functioning: New theoretical and therapeutic perspectives]. *L'Encephale*, *40*(2), 160–167. https://doi.org/10.1016/j.encep.2012.06.004

Mattila, A. K., Kronholm, E., Jula, A., Salminen, J. K., Koivisto, A.-M., Mielonen, R.-L., & Joukamaa, M. (2008). Alexithymia and somatization in general population. *Psychosomatic Medicine*, *70*(6), 716–722. https://doi.org/10.1097/PSY.0b013e31816ffc39

McCrimmon, A., & Rostad, K. (2014). Test Review: Lord, C., Luyster, R. J., Gotham, K., & Guthrie, W. (2012). "Autism Diagnostic Observation Schedule, Second Edition (ADOS-2) Manual (Part II): Toddler Module." Torrance, CA: Western Psychological Services, 2012. Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. "Autism Diagnostic Observation Schedule, Second Edition." Torrance, CA: Western Psychological Services, 2012. *Journal of Psychoeducational Assessment*, *32*(1), 88–92. https://doi.org/10.1177/0734282913490916

Micali, N., Hagberg, K. W., Petersen, I., & Treasure, J. L. (2013). The incidence of eating disorders in the UK in 2000-2009: Findings from the General Practice Research Database. *BMJ Open*, *3*(5), e002646. https://doi.org/10.1136/bmjopen-2013-002646

Milos, G., Spindler, A., Schnyder, U., & Fairburn, C. G. (2005). Instability of eating disorder diagnoses: Prospective study. *The British Journal of Psychiatry: The Journal of Mental Science*, *187*, 573–578. https://doi.org/10.1192/bjp.187.6.573

Miniati, M., Callari, A., Maglio, A., & Calugi, S. (2018). Interpersonal psychotherapy for eating disorders: Current perspectives. *Psychology Research and Behavior Management*, *11*, 353–369. https://doi.org/10.2147/PRBM.S120584

Miniati, M., & Marazziti, D. (2019). Psychopharmacological options for adult patients with anorexia nervosa: The patients' and carers' perspectives integrated by the spectrum model. *CNS Spectrums*, *24*(2), 225–226. https://doi.org/10.1017/S1092852917000700

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA

Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, *6*(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Mundt, J. C., Marks, I. M., Shear, M. K., & Greist, J. H. (2002). The Work and Social Adjustment Scale: A simple measure of impairment in functioning. *The British Journal of Psychiatry: The Journal of Mental Science*, *180*, 461–464. https://doi.org/10.1192/bjp.180.5.461

Pooni, J., Ninteman, A., Bryant-Waugh, R., Nicholls, D., & Mandy, W. (2012). Investigating autism spectrum disorder and autistic traits in early onset eating disorder. *The International Journal of Eating Disorders*, *45*(4), 583–591. https://doi.org/10.1002/eat.20980

Porges, S. W. (1993). Body perception questionnaire. Laboratory of Developmental Assessment: University of Maryland.

Rhind, C., Bonfioli, E., Hibbs, R., Goddard, E., Macdonald, P., Gowers, S., Schmidt, U., Tchanturia, K., Micali, N., & Treasure, J. (2014). An examination of autism spectrum traits in adolescents with anorexia nervosa and their parents. *Molecular Autism*, *5*(1), 56. https://doi.org/10.1186/2040-2392-5-56

Ruggieri, V. L. (2014). [The amygdala and its relation to autism, behavioural disorders and other neurodevelopmental disorders]. *Revista De Neurologia*, *58 Suppl 1*, S137-148.

Saure, E., Lepistö-Paisley, T., Raevuori, A., & Laasonen, M. (2022). Atypical Sensory Processing Is Associated With Lower Body Mass Index and Increased Eating Disturbance in Individuals With Anorexia Nervosa. *Frontiers in Psychiatry*, *13*, 850594. https://doi.org/10.3389/fpsyt.2022.850594

Schardt, C., Adams, M. B., Owens, T., Keitz, S., & Fontelo, P. (2007). Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Medical Informatics and Decision Making*, *7*, 16. https://doi.org/10.1186/1472-6947-7-16

Sheehan, D. V., Lecrubier, Y., Sheehan, K. H., Amorim, P., Janavs, J., Weiller, E., Hergueta, T., Baker, R., & Dunbar, G. C. (1998). The Mini-International Neuropsychiatric Interview (M.I.N.I.): The development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *The Journal of Clinical Psychiatry*, *59 Suppl 20*, 22-33;quiz 34-57.

Social Responsiveness Scale, 2nd Edition (SRS-2) | Pearson Clinical Australia & New Zealand. (n.d.). Retrieved April 25, 2022, from https://www.pearsonclinical.com.au/products/view/512

Spek, A. A., van Rijnsoever, W., van Laarhoven, L., & Kiep, M. (2020). Eating Problems in Men and Women with an Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *50*(5), 1748–1755. https://doi.org/10.1007/s10803-019-03931-3

Sternheim, L., Startup, H., Pretorius, N., Johnson-Sabine, E., Schmidt, U., & Channon, S. (2012). An experimental exploration of social problem solving and its associated processes in anorexia nervosa. *Psychiatry Research*, *200*(2–3), 524–529. https://doi.org/10.1016/j.psychres.2012.06.029

Tauro, J. L., Wearne, T. A., Belevski, B., Filipčíková, M., & Francis, H. M. (2022). Social cognition in female adults with Anorexia Nervosa: A systematic review. *Neuroscience and Biobehavioral Reviews*, *132*, 197–210. https://doi.org/10.1016/j.neubiorev.2021.11.035

Tchanturia, K., Doris, E., & Fleming, C. (2014). Effectiveness of cognitive remediation and emotion skills training (CREST) for anorexia nervosa in group format: A naturalistic pilot study. *European Eating Disorders Review: The Journal of the Eating Disorders Association*, *22*(3), 200–205. https://doi.org/10.1002/erv.2287

Tchanturia, K., Doris, E., Mountford, V., & Fleming, C. (2015). Cognitive Remediation and Emotion Skills Training (CREST) for anorexia nervosa in individual format: Self-reported outcomes. *BMC Psychiatry*, *15*, 53. https://doi.org/10.1186/s12888-015-0434-9

Treasure, J., & Schmidt, U. (2013). The cognitive-interpersonal maintenance model of anorexia nervosa revisited: A summary of the evidence for cognitive, socio-emotional and interpersonal predisposing and perpetuating factors. *Journal of Eating Disorders*, *1*, 13. https://doi.org/10.1186/2050-2974-1-13

Võ, M. L.-H., Smith, T. J., Mital, P. K., & Henderson, J. M. (2012). Do the eyes really have it? Dynamic allocation of attention when viewing moving faces. *Journal of Vision*, *12*(13), 3. https://doi.org/10.1167/12.13.3

Vuillier, L., Carter, Z., Teixeira, A. R., & Moseley, R. L. (2020). Alexithymia may explain the relationship between autistic traits and eating disorder psychopathology. *Molecular Autism*, *11*(1), 63. https://doi.org/10.1186/s13229-020-00364-z

WASI-II - Wechsler Abbreviated Scale of Intelligence—Second Edition—EPROVIDE™. (n.d.). Retrieved April 25, 2022, from https://eprovide.mapi-trust.org/instruments/wechsler-abbreviated-scale-of-intelligence-second-edition

Wechsler, D. (1997) WAIS-III administration and scoring manual, The Psychological Corporation, San Antonio, TX.

Westwood, H., Mandy, W., & Tchanturia, K. (2017). Clinical evaluation of autistic symptoms in women with anorexia nervosa. *Molecular Autism*, *8*, 12. https://doi.org/10.1186/s13229-017-0128-x

Westwood, H., & Tchanturia, K. (2017). Autism Spectrum Disorder in Anorexia Nervosa: An Updated Literature Review. *Current Psychiatry Reports*, *19*(7), 41. https://doi.org/10.1007/s11920-017-0791-9

Zhou, Z. C., McAdam, D. B., & Donnelly, D. R. (2018). Endophenotypes: A conceptual link between anorexia nervosa and autism spectrum disorder. *Research in Developmental Disabilities*, *82*, 153–165. https://doi.org/10.1016/j.ridd.2017.11.008

Zigmond, A. S., & Snaith, R. P. (1983). The hospital anxiety and depression scale. *Acta Psychiatrica Scandinavica*, *67*(6), 361–370. https://doi.org/10.1111/j.1600-0447.1983.tb09716.x

Zucker, N. L., Losh, M., Bulik, C. M., LaBar, K. S., Piven, J., & Pelphrey, K. A. (2007). Anorexia nervosa and autism spectrum disorders: Guided investigation of social cognitive endophenotypes. *Psychological Bulletin*, *133*(6), 976–1006. https://doi.org/10.1037/0033-2909.133.6.976