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Emotional regulation deficits in autism spectrum disorder: The role of alexithymia and interoception

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ABSTRACT

The aim of this study was to analyze emotional regulation, alexithymia and interoception in a group of people diagnosed with ASD (n = 27), a normative population with a technical academic training (n = 30), and another group with a humanities/health training (n = 20). Results showed significantly higher scores in alexithymia and emotional regulation problems, and lower scores in interoception in the ASD group. Also, alexithymia was found to correlate with emotional regulation, which was found to be significant in all three groups. In addition, interoception correlated negatively with alexithymia in the ASD group. Finally, the scores of the group with the technical training were closer to those of the ASD group compared to the humanities/health group.

1. Background

Autism Spectrum Disorder (ASD) is a condition related to brain development with high prevalence worldwide (Lai et al., 2014). World's population has been found to have this pathology around 0.67%, affecting 4-5 times more males than females. ASD encompasses multidimensional symptoms from behavioral problems such as repetitive movements, restricted interests, difficulties in nonverbal communication and hypo- or hyper-reactivity to stimuli (Alison et al., 2010). DSM-5 organizes ASD into three levels according to the degree of severity and need of support of the individual; (Kristian & Craig, 2016); from barely any need to substantial therapeutic motor, cognitive, behavioral, and social support (Mazefsky et al., 2013). Moreover, emotional regulation difficulties and emotional processing are also prevalent in ASD population, following less adaptive pattern of emotional regulation strategies (Cai et al., 2018). However, the recent research has been inconsistent not permitting to categorize these difficulties as a main characteristic of ASD (Kinnaird et al., 2019).

In parallel, it has been reported that people with ASD prefer activities related to mathematics, exact sciences, technologies, engineering, etc. (Wei et al., 2013). Brain structures such as the medial prefrontal cortex, amygdala, frontal area, and hippocampus -areas linked to ASD- have been studied by MRI, and it has been found that such brain structures in students of exact sciences have similarities with these brain structures in people with ASD traits. The opposite being, in students with a non-technical academic training: humanities, health sciences, philology, etc., the hippocampal structure is smaller, causing them to score lower in cognitive skills such as spatial orientation (Takeuchi et al., 2015); and the amygdala was found to be significantly larger, increasing the score in empathy (Takeuchi et al., 2015).

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On the other hand, the phenotypic manifestation of ASD is different in adulthood, where emotional regulation problems -derived from an difficulties in emotional awareness, interpretation and control- increase, causing a slow and dysfunctional cognitive-emotional development (Hofvander et al., 2009). This deficit explains the comorbidity with certain mood and behavioral disorders that are very frequent in ASD, being depression, anxiety and aggressiveness the most frequent ones (Conner et al., 2019). Thus, deficits in emotional regulation in people with ASD could be explained by the participation of two main variables: alexithymia and interoception (Shah, Catmur, et al., 2016). Alexithymia, posed as a personality construct (Gori et al., 2012), is closely linked to other psychiatric disorders (Poquérusse et al., 2018) and is described as a difficulty in describing feelings and verbalizing bodily sensations (Kinnaird et al., 2019). Alexithymia is a variable personality trait, where each person presents a higher or lower degree of alexithymia (Fernandez Montalvo & Yárnoz, 1994). In relation to ASD, alexithymia presents a comorbidity of 50% (Poquérusse et al., 2018) and exerts an important and complex role in emotion regulation. In fact, alexithymia has been found to be very similar to the socioemotional difficulties of individuals with ASD, symptoms such as difficulty in identifying and attributing emotions, lack of pragmatic understanding, poor emotional lexicon and prosody (Shah, Catmur, et al., 2016). However, several studies explain that such socioemotional tendency only occurs in individuals with ASD when alexithymia is also present (Cai et al., 2018; Costa et al., 2017; Morie et al., 2019; Ryan et al., 2020), thus justifying that difficulties in emotional intelligence are present in people with ASD but not related to it. Therefore the *Alexithymia Hypothesis* arises suggesting that difficulties in emotional processing in people with ASD are actually a product of alexithymia (Bird & Cook, 2013; Kinnaird et al., 2019).

The second factor also related to emotional regulation in people with ASD is interoception. Sherrington, who was the first to use this construct, labeled interoception as the ability to define and perceive visceral sensations, as well as internal experiences such as pain, hunger or thirst (Ceunen et al., 2016). The concept of interoception is not a single element, but is characterized by its multidimensionality (Mehling et al., 2018); encompassing the ability to perceive bodily sensations, but also, the ability to maintain attention, regulation and emotional awareness to the perceived sensation. This factor is not simple to study since it can be explained from different perspectives and justified through different approaches. For example, from the Polyvagal Theory (Porges, 2007), which explains the relationship of the Autonomic Nervous System (ANS) with human behavior patterns, by proposing three neurological systems closely related to basic emotional responses, such as fight or flight, but also involved with social factors. From this approach, interoception has been considered as a modulator of the control of the physiological responses of the ANS leading to better social patterns and abilities; making the intervention in interoceptive awareness lead to better socioemotional responses.

At the biological level, interoception is related to brain regions similar to those of alexithymia (Borsci et al., 2009; Goerlich-Dobre et al., 2014; Paradiso et al., 2008) and ASD, as it actually coincides in the abnormalities found, for the most part, in regions within the insula and anterior cingulate cortex (Murphy et al., 2017). These regions have been related to the neurobiology of ASD, in fact, hypo- or hyperreactivity to stimuli, a very frequent symptom in ASD, has been related to interoception, even some studies justify that it is one of the main causes of this alteration (Alison et al., 2010; Fiene & Brownlow, 2015; Rogers & Ozonoff, 2005).

However, both alexithymia and interoception are related to each other and together interfere with emotional regulation (Nicholson et al., 2019). First, studies suggest that interoceptive problems are at the root of alexithymia. In a study by Shah, Catmur, et al. (2016) they found that those participants who score high on alexithymia also have low levels of interoception, so they concluded that alexithymia is best characterized by a general failure in interoception. On the other hand, other research suggests that although both factors may influence each other, they are independent constructs (Manzoor et al., 2021) and that alexithymia works by enhancing the subject's negative experience, causing them to come up with catastrophizing interpretations (Palser et al., 2018).

In summary, alexithymia and interoception are two factors that actively participate in the emotional regulation of individuals with ASD; although it is still questioned whether they are dependent variables (Shah, Hall, et al., 2016), they have been found to be highly implicated and influential to each other in the emotional experience. Considering what has been explained, the main objective of this study is to investigate how alexithymia and interoception influence emotional regulation in people with ASD. For this purpose, the following strategy has been followed. Considering that the diagnosis of ASD is divided into three levels depending on the severity of the symptomatology presented and not as a static disorder, and taking into account the proximity of certain populations, such as people with technical academic training (engineering, mathematics, technology, etc.), to the features of ASD, a comparison will be made between the group with ASD and a control group divided into a sample with technical academic training and a sample with non-technical academic training (history, teaching, health sciences, etc.). In this way, it is expected that the population with technical academic training will be significantly closer to the characteristics of ASD, in terms of the levels and dynamics of emotional regulation, alexithymia and interoception. At the same time, we hypothesize that there will be significant differences in alexithymia and interoception between the control populations with respect to the ASD group. Furthermore, in order to test the relationship between all the variables indicated, we will analyze the relationship between all the above variables among the three groups. It is expected to find that low scores in interoception and high scores in alexithymia will imply low scores in emotional regulation (Bird & Cook, 2013; Goerlich-Dobre et al., 2014; Nicholson et al., 2019).

2. Method

2.1. Design

The study design is empirical, cross-sectional and descriptive-comparative. The main purpose will be to make a comparison of results between the groups according to the levels of alexithymia, interoception and emotional regulation.

2.2. Participants

The final sample of this research was composed by 77 participants, organized in three groups; on the one hand, a sample of people with technical academic training (n=30); 16 women (53.3%) and 14 men (46.7%), that means belonging to engineering, technology or similar academic fields, there were participants with computer, mechanical, industrial, aerospace and biotechnologies engineering training (age: M = 22.43, SD=6.112). And on the other hand, the group of non-technical training, in which participants do not follow any academic training presented above, for instance, humanities and health sciences were the fields in this group (n = 20), in which 3 were men (15%) and 17 were women (85%) (age: M = 28.39 D=11.54). Finally, 27 participants belong to the ASD group (age: M= 31.8, SD=10.617). This group was clinically diagnosed using the following protocol: firstly, an anamnestic interview was conducted, where basic information about the patient was collected, and then another family interview or interview with close people, including relatives, friends, partners or other significant people. Such interviews were closed with personal documentation of personal experiences. Secondly, standardized psychopathological tests were administered:

- MCMI-IV (Million IV): allows the assessment of personality patterns, psychopathological manifestations and associated comorbidities.
- Autism Spectrum Quotient (AQ): this scale allows discriminating degrees of autism phenotype (low, medium or high).
- TECA Questionnaire (Cognitive and Affective Empathy Test): this tool assesses emotional understanding, empathic stress and empathic joy.
- Test of Creative Imagination for Adults (PIC-A), which assesses *Fluency* (total number of ideas in a task), *Flexibility* (number of different categories), *Originality* (degree of infrequency) and *Elaboration* (length or detail).
- Brief intelligence test K-BIT, which allows the general assessment of fluid and crystallized intelligence and assesses an indicative IQ of the general intelligence level.

Finally, the diagnosis ends up respecting the DSM 5 criteria. Based on the fulfillment of these criteria, the diagnosis will be determined according to specifiers and level of severity.

2.3. Measurements

2.3.1. TAS-20: Toronto Alexithymia Scale

The TAS-20 scale (Toronto Alexithymia Scale) (Bagby et al., 1994) evaluates the levels of alexithymia, consisting of 20 questions with Likert-type answers ranging from 1 to 4, assessing three subscales: Difficulty in Describing Feelings, Difficulty in Identifying Feelings; and Externally Oriented Thinking, as well as the Alexithymia total score. The Cronbach's alpha values obtained in each variable were above.80.

2.3.2. BPQ-SV: Body Perception Questionnaire – short version

To assess interoceptive ability (Wang et al., 2020) a short version of the BPQ was used, consisting of a 12-item questionnaire with Likert-type responses ranging from 1 to 5. The reliability obtained, in Cronbach's alpha coefficient, is.905.

2.3.3. DERS: difficulties in Emotional Regulation Scale

The Difficulty in Emotion Regulation Scale (DERS) (Gratz & Roemer, 2004) was used to assess difficulties in Emotion Regulation. The scale is designed to measure difficulties in emotional regulation; in this case, the Spanish adaptation was used, which has 28 items with a Likert-type response style ranging from 1 to 5 (Hervás & Jódar, 2008). Including its five subscales: Nonacceptance of Emotional Responses, Difficulty Engaging in Goal-Directed Behavior, Impulse Control Difficulties, Lack of Emotional Awareness, and Lack of Emotional Clarity. The Cronbach's alpha values obtained in each variable were above.70.

2.3.4. AQ: Autism Spectrum Quotient

It consists of an evaluative tool of autistic traits -Autism Spectrum Quotient -, it measures five main dimensions: social skills, attention switching, attention to details, communication and imagination, in addition to the global dimension that allows discriminating degrees of autism phenotype (in low, medium or high autism quotient). The scale has 50 items with Likert-type response style ranging from 1 to 4 (Baron-Cohen et al., 2001). In the present study only the global dimension was used. The reliability obtained in the sample collected, in Cronbach's alpha coefficient, is.754.

2.4. Procedure

This study guarantees the anonymity and confidentiality of all participants, respecting the principles of the Declaration of Helsinki (1964) and ethical standards of data protection of the Organic Law 15/1999 of December 13. Thus, this study has been approved by the Ethics Research Committee of the University of Valencia. This research was carried out as follows: first, we proceeded to the recruitment of participants, where we collected, on the one hand, a sample of the ASD population through contact with an association of ASD-Asperger and a Psychology Center specialized in the diagnosis and treatment of the Autism Spectrum Disorder. On the other hand, volunteers with training in various academic fields were contacted and organized into two samples: a group of technical academic training and a group of non-technical academic training. Once the participants signed the informed consent, they filled in a

battery consisting of an anonymous form where they were asked about age, gender, academic branch, and socioeconomic status, and the four main questionnaires: TAS-20, BPQ, DERS and AQ.

2.5. Statistical analysis

The data collected were analyzed using the SPSS 23.0. First, it was verified that all the variables used (AQ, TAS-20, DERS and BPQ) followed a normal distribution by means of the Kolmogorov-Smirnoff test. After that, differences were studied using the univariate general linear model (ANOVA) with Bonferroni's *Post Hoc* multiple comparisons analysis. The significance level was assigned to 0.05 and both partial eta squared (η^2p), being the effect size, and power (1-β) were taken into account. The study of the relationships between variables was done through Pearson correlations.

3. Results

3.1. Preliminary analysis

Firstly, to control the effect of age and gender, these variables were covaried, since significant differences were found in these variables (see Table 1).

3.1.1. Between-group comparison in alexithymia, interoception and emotional regulation

The results obtained are detailed in Table 2, which shows the mean scores obtained for each group (ASD, technical and non-technical academic training) and the significant differences.

First, in regard to the total scores of each variable, significant differences were found in alexithymia $F_{(4, 72)} = 4.758$, $p = .002$, $\eta^2p = .209$, power = .941. As can be seen in Table 2, the ASD group presented higher and significant scores with respect to the other groups. The lowest score was in non-technical academic training group, being the effect size strong ($p > .05$, $\eta^2p = .209$). However, there were no significant differences between both academic training, although the effect size was strong ($p > .05$, $\eta^2p = .209$). In Table 3 post hoc analysis between alexithymia subscales are shown, noting the same results as with the total score; that is, ASD group scores differed significantly between the other two groups.

Regarding interoception, higher scores were seen in the non-technical training, followed by the Technical training and ASD sample, $F_{(4, 72)} = 2.124$, $p = .087$, $\eta^2p = .106$, power = .602. Nevertheless, there were no significant differences between the ASD group and the Technical training group ($p = .493$, $\eta^2p = .106$), nor with the non-technical training group ($p = .093$, $\eta^2p = .106$). On the other hand, there were no significant differences between the training groups ($p > .05$, $\eta^2p = .106$). However, it must be taken into account that the size of the effect was moderate in the three differences.

Further, problems in emotional regulation $F_{(4, 72)} = 5.015$, $p = .01$, $\eta^2p = .218$, power = .952 were higher in the ASD group, again, showing significant differences ($p = .003$, $\eta^2p = .218$) with the groups of technical and non-technical academic training ($p = .01$, $\eta^2p = .218$). Between the two groups of academic training, there were no significant differences ($p > .05$, $\eta^2p = .218$) although the effect size was strong in the three comparisons. In Table 4 post hoc analysis between subscales are presented, in which in the same line as the total scale; that is, differences in Difficulty engaging in goal-directed, Impulse control difficulties were found, and Lack of emotional clarity scoring in more difficulties in ASD in comparison to the other two groups.

Finally, with respect to the Autism Spectrum Quotient, a one-way ANOVA was performed to study the differences between the technical and non-technical academic training groups. As can be seen in the table, significant differences appeared $F_{(4, 29)} = 3.105$, $p = .03$, $\eta^2p = .300$, power = .743, with a strong effect size, with the technical academic training group scoring higher.

3.1.2. Relationships between variables as a function of the group

A study of partial correlations in each of the groups: ASD Group, Technical and Non-Technical academic training, in which Age and Gender variables were controlled. Correlations between subscales are shown in Table 5.

3.2. Correlations in the ASD group

Studying the relationship between the total scores in the ASD group, we found that all the variables correlated significantly with

Table 1
Frequencies shows technical, non-technical and ASD group.

	ASD (N = 27)	Technical (N = 30)	Non-technical (N = 20)	F	df between	df within	*p-value*
Age	*M* = 32.5 ± 10.4	*M* = 22.4 ± 6.1	*M* =28.9 ± 11.5	8.1**	2	74	.001
Gender				3.9*	2	74	.025
Men	50%	53.3%	15%				
Women	50%	46.7%	85%	2.5	2	74	.085
Socioeconomic status	*M* =5.9 ± 1.2	*M* = 6.4 ± 1.2	*M* = 6.7 ± 1.3	2.2	2	74	.079

M, mean; ±, SD. *Socioeconomic status*, 1; very low, 10; very high. *Significant contrast at the.05 level. **Significant contrast at the.01 level.

Table 2
Means, standard deviations and significant differences in alexithymia, interoception, difficulties in emotional regulation and autism spectrum quotient.

	ASD Group	Technical training	Non-technical training	F	df between	df within	*p-value*	η^2p	*1-β*
TAS-DDF	17.1 ± 5.5	17.3 ± 4.8	11.6 ± 4.7	3.9**	4	72	***p*=.006**	.180	.886
TAS-DIF	20.6 ± 7.1	15.1 ± 5.2	14.05 ± 6.2	4.5**	4	72	***p*=.003**	.199	.925
TAS-EOT	21.3 ± 5.1	17.3 ± 4.2	19.4 ± 4.9	2.8*	4	72	***p*=.031**	.135	.742
TAS-TOTAL	59.0 ± 15.2	46.6 ± 9.9	45.0 ± 12.3	4.8**	4	72	***p*=.002**	.209	. 941
DERS-NONACCEPTENCE	18.5 ± 7.2	14.5 ± 7.2	13.2 ± 5.1	2.1	4	72	*p=.83*	.107	.608
DERS-GOALS	16.3 ± 3.6	12.57 ± 4.6	12.5 ± 4.2	3.8**	4	72	***p*=.007**	.175	.875
DERS-AWARENESS	-14.0 ± 3.62	-15.4 ± 3.1	-15.8 ± 2.28	1.5	4	72	*p=.221*	.075	.433
DERS-CLARITY	5.9 ± 4.5	3.13 ± 3.8	1.8 ± 3.1	4.3**	4	72	***p*=.004**	.19	.910
DERS-CONTROL	29.6 ± 7.9	22.9 ± 10.5	20.2 ± 8.4	.4.3**	4	72	***p*=.003**	.193	.915
DERS TOTAL	86.4 ± 19.5	67.7 ± 22.7	67.8 ± 19.6	5.**	4	72	***p*<.001**	.218	.952
BPQ	36.6 ± 9.6	40.8 ± 12.4	43.9 ± 11.6	2.1	4	72	*p*=.087	. 106	. 602
AQ	—**	22.1 ± 6.4	16.9 ± 5.8	3.1*	4	29	***p*=.03**	. 300	. 743

*Significant contrast at the .05 level; **Significant contrast at the .01 level. The ASD group has been clinically diagnosed so the questionnaire was not used in this sample. Univariate ANOVA between technical and non-technical academic training groups. TAS-DDF, Difficulty in Describing Feelings; TAS-DIF, Difficulty in Identifying Feelings; TAS-EOT, Externally Oriented Thinking; TAS-TOTAL, Alexithymia total score; DERS-NONACCEPTENCE, Nonacceptance of emotional responses; DERS-GOALS, Difficulty engaging in goal-directed behavior: DERS-AWARENESS, Lack of emotional awareness; DERS-CLARITY, Lack of emotional clarity; DERS-CONTROL, Impulse control difficulties; DERS-TOTAL, Difficulties in emotional regulation total score; BPQ, Interoception; AQ, Autism Spectrum Quotient. In bold the significant differences between ASD and technical/non-technical academic training are shown.

each other. Specifically, alexithymia obtained a negative, moderate and significant correlation with interoception $r_{(23)}$ = -.510, p =.009 and positive, strong and significant with emotional regulation $r_{(23)}$ =.757, p =.01. On the other hand, the correlation between problems in emotional regulation and interoception was negative, moderate and significant $r_{(23)}$ =.-461, p =.020.

In regard to the correlations between subscales (Table 5), Difficulty in Identifying Feelings positively correlated with Difficulty engaging in goal-directed behavior, Lack of emotional clarity, Impulse control difficulties, as well as negatively with interoception.

In other hand, Dificulty in Describing Feelings correlated significantly with Nonacceptance of emotional responses, Difficulty engaging in goal-directed behavior, Lack of emotional awareness, Lack of emotional clarity and Impulse control difficulties, and negatively with interoception.

Regarding alexithymia total score, this correlated positively with all problems in emotional regulation scales. Finally, Externally Oriented Thinking correlated positively with all problem in emotional regulation subscales, as well as negatively with interoception.

3.3. Correlations in technical academic training and non-technical academic training

Among the total variables in the Technical Academic training sample, alexithymia showed a non-significant correlation with interoception (p>.05), but with problems in emotional regulation appeared a positive, strong and significant correlation $r_{(10)}$ =. 689, p =.013. On the other hand, the correlation between interoception and problems in emotional regulation was not significant either (p>.05). Finally, there was no significant correlation between the Autism Spectrum Quotient and the three variables (p>.0.5).

Regarding subscales correlations (Table 5), it was found that Difficulty in identifying feelings correlated positively with Nonacceptance of emotional responses, Lack of emotional clarity and Impulse control difficulties.

In another hand, Difficulty in describing feelings correlated positively with Lack of emotional awareness, Nonacceptance of emotional responses, Lack of emotional clarity, and Impulse control difficulties.

Regarding Externally oriented thinking, positive correlations was found with Nonacceptance of emotional responses, Difficulty engaging in goal-directed behavior, Lack of emotional clarity, Impulse control difficulties.

In another hand, the alexithymia total score correlated significantly with Nonacceptance of emotional responses, Difficulty engaging in goal-directed behavior, Lack of emotional clarity, and Impulse control difficulties. However, no significant correlations were found with interoception.

As for the Non-technical Academic training group, the correlations between alexithymia with interoception, again, appeared non-significant (p>.05), but alexithymia correlated positively and significantly with problems in emotional regulation, $r_{(16)}$ =.628, p =.005. On the other hand, interoception and problems in regulation did not correlate significantly (p>.05). However, in this case the Autistic Spectrum Quotient obtained a moderate positive significant correlation with alexithymia $r_{(16)}$ =.499, p =.035 and problems in emotional regulation $r_{(16)}$ =.489, p =.04, but not significant with interoception (p>.05).

Between subscales correlations (Table 5), it was found that Difficulty in identifying feelings correlated positively with Nonacceptance of emotional responses, Difficulty engaging in goal-directed behavior, Lack of emotional clarity and Impulse control difficulties.

In another hand, Difficulty in describing feelings only correlated positively with Lack of emotional clarity. Regarding Externally oriented thinking, positive correlations were found between all subscales.

Alexithymia total score correlated significantly with Difficulty engaging in goal-directed behavior, Lack of emotional awareness, Lack of emotional clarity, and Impulse control difficulties. However, no significant correlations were found with interoception.

Table 3
Bonferroni post hoc test for pairwise comparisons of the groups in alexithymia.

	Comparison		Mean Difference	Std.Error	Sig.	95% Confidence Interval	
Dependent Variable	Condition	Condition				Lower Bound	Upper Bound
TAS-DIF	technical	non-technical	1.0	1.885	1.000	-3.614	5.628
		ASD	-6.3**	1.823	**.003**	-10.805	-1.870
	non-technical	technical	-1.0	1.885	1.000	-5.628	3.614
		ASD	-7.4**	1.947	**.001**	-12.116	-2.573
	ASD	technical	6.4**	1.823	**.003**	1.870	10.805
		non-technical	7.4**	1.947	**.001**	2.573	12.116
TAS-DDF	technical	non-technical	1.8	1.542	.711	-1.940	5.617
		ASD	-3.6	1.490	.055	-7.251	.056
	non-technical	technical	-1.8	1.542	.711	-5.617	1.940
		ASD	-5.4**	1.592	**.003**	-9.338	-1.534
	ASD	technical	3.6	1.490	.055	-.056	7.251
		non-technical	5.4**	1.592	**.003**	1.534	9.338
TAS-EOT	technical	non-technical	-2.1	1.442	.479	-5.584	1.486
		ASD	-3.5*	1.394	**.045**	-6.886	-.051
	non-technical	technical	2.0	1.442	.479	-1.486	5.584
		ASD	-1.4	1.489	1.000	-5.070	2.231
	ASD	technical	3.5*	1.394	**.045**	.051	6.886
		non-technical	1.4	1.489	1.000	-2.231	5.070
TAS-TOTAL	technical	non-technical	.7	3.886	1.000	-8.729	10.322
		ASD	-13.4**	3.757	**.002**	-22.612	-4.195
	non-technical	technical	-.8	3.886	1.000	-10.322	8.729
		ASD	-14.2**	4.013	**.002**	-24.036	-4.365
	ASD	technical	13.4**	3.757	**.002**	4.195	22.612
		non-technical	14.2**	4.013	**.002**	4.365	24.036

*Significant contrast at the .05 level; **Significant contrast at the .01 level. TAS-DDF, Difficulty in Describing Feelings; TAS-DIF, Difficulty in Identifying Feelings; TAS-EOT, Externally Oriented Thinking; TAS-TOTAL, Alexithymia total score. In bold the significant differences between ASD and technical/non-technical academic training are shown.

4. Conclusions and implications

Focusing on the main hypothesis of this work, comparing alexithymia, interoception and emotion regulation as a function of belonging to different groups (ASD group, technical academic training group and non-technical academic training group), we found that there were indeed significant differences between the ASD group and the two groups of technical and non-technical academic training, showing significantly higher scores in alexithymia, and at the same time, lower scores in interoception and emotion regulation. Additionally, although no differences between the non-ASD groups were found, the effect size has been shown to be strong, so we can attribute that no significant differences were shown due to the number of participants. Complementarily, we analyzed the relationship between these variables according to the group, finding that there were significant Pearson's rs between the 3 variables in the ASD group, correlating, on the one hand, alexithymia negatively with interoception, while both variables correlated positively with problems in emotional regulation. This result was repeated in the technical and non-technical academic training groups; however, interoception did not correlate significantly with alexithymia in either of these two groups. When we considered subscales of

Table 4
Bonferroni post hoc test for pairwise comparisons of the groups in problems in emotional regulation.

	Comparison		Mean Difference	Std.Error	Sig.	95% Confidence Interval	
Dependent Variable	Condition	Condition				Lower Bound	Upper Bound
DERS-NONACCEPTENCE	technical	non-technical	1.3	2.096	1.000	-3.881	6.392
		ASD	-4.5	2.026	.084	-9.512	.421
	non-technical	technical	-1.3	2.096	1.000	-6.392	3.881
		ASD	-5.8*	2.164	**.027**	-11.105	-.497
	ASD	technical	4.5	2.026	.084	-.421	9.512
		non-technical	5.8*	2.164	**.027**	.497	11.105
DERS-GOALS	technical	non-technical	-.3	1.288	1.000	-3.452	2.863
		ASD	-4.4**	1.245	**.002**	-7.424	-1.319
	non-technical	technical	.3	1.288	1.000	-2.863	3.452
		ASD	-4.1**	1.330	**.009**	-7.337	-.817
	ASD	technical	4.4*	1.245	**.002**	1.319	7.424
		non-technical	4.1**	1.330	**.009**	.817	7.337
DERS-AWARENESS	technical	non-technical	.04	.956	1.000	-2.300	2.385
		ASD	-1.5	.924	.303	-3.799	.730
	non-technical	technical	-.04	.956	1.000	-2.385	2.300
		ASD	-1.6	.987	.343	-3.995	.842
	ASD	technical	1.5	.924	.303	-.730	3.799
		non-technical	1.6	.987	.343	-.842	3.995
DERS-CLARITY	technical	non-technical	1.1	1.185	1.000	-1.857	3.955
		ASD	-3.1**	1.146	**.007**	-6.426	-.808
	non-technical	technical	-1.0	1.185	1.000	-3.955	1.857
		ASD	-4.7**	1.224	**.001**	-7.666	-1.665
	ASD	technical	3.6**	1.146	**.007**	.808	6.426
		non-technical	4.7*	1.224	**.001**	1.665	7.666
DERS-CONTROL	technical	non-technical	3.8	2.775	.524	-2.997	10.609
		ASD	-7.3*	2.683	**.025**	-13.855	-.701
	non-technical	technical	-3.8	2.775	.524	-10.609	2.997
		ASD	-11.1**	2.866	**.001**	-18.108	-4.059
	ASD	technical	7.3*	2.683	**.025**	.701	13.855
		non-technical	11.1**	2.866	**.001**	4.059	18.108
DERS-TOTAL	technical	non-technical	5.9	6.386	1.000	-9.795	21.510
		ASD	-21.4**	6.174	**.003**	-36.479	-6.214
	non-technical	technical	-5.9	6.386	1.000	-21.510	9.795
		ASD	-27.2**	6.594		-43.367	-11.042

(*continued on next page*)

Table 4 (*continued*)

Dependent Variable	Comparison Condition	Condition	Mean Difference	Std.Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
					.000		
	ASD	technical	21.3**	6.174		6.214	36.479
					.003		
		non-technical	27.2**	6.594		11.042	43.367
					.000		

*Significant contrast at the.05 level; **Significant contrast at the.01 level; DERS-NONACCEPTENCE, Nonacceptance of emotional responses; DERS-GOALS, Difficulty engaging in goal-directed behavior: DERS-AWARENESS, Lack of emotional awareness; DERS-CLARITY, Lack of emotional clarity; DERS-CONTROL, Impulse control difficulties; DERS-TOTAL, Difficulties in emotional regulation total score. In bold the significant differences between ASD and technical/non-technical academic training are shown.

Table 5
Pearson correlations between alexithymia, interoception and, problems in emotional regulation in each group.

ASD group		DERS-NONACCEPTENCE	DERS-GOALS	DERS-AWARENESS	DERS-CLARITY	DERS-CONTROL	DERS-TOTAL	BPQ
TAS-DIF	Pearson's r	.350	.454**	.303	.821**	.528**	.668**	-.482*
	sig	.086	**.001**	.141	**.001**	**.007**	**.001**	**.015**
TAS-DDF	Pearson's r	.418*	.408*	.294	.8**	.402*	.634*	-.459*
	sig	**.038**	**.043**	.153	**.001**	**.047**	**.001**	**.021**
TAS-EOT	Pearson's r	.570**	.419*	.488*	.481*	.411*	.651**	-.361
	sig	**.003**	**.037**	**.013**	**.015**	**.041**	**.001**	.076
TAS_TOTAL	Pearson's r	.505**	.498*	.411*	.838**	.528**	.757**	-.510**
	sig	**.010**	**.011**	**.041**	**.001**	**.007**	**.001**	**.009**
BPQ_TOTAL	Pearson's r	-.134	-.605**	-.129	-.5**	-.390	-.461*	
	sig	.500	**.001**	.538	**.008**	.054	**.020**	
Technical academic training group								
TAS-DIF	Pearson's r	.882**	.371	.113	.777**	.791**	.867**	-.011
	sig	**.001**	.052	.568	**.001**	**.001**	**.001**	.955
TAS-DDF	Pearson's r	.590**	.370	.220**	.818**	.679**	.742**	-.300
	sig	**.001**	.052	**.001**	**.001**	**.001**	**.001**	.409
TAS-EOT	Pearson's r	-.085	.300	.219	.049	-.055	.031	.088
	sig	.667	.200	.200	.803	.781	.874	.657
TAS-TOTAL	Pearson's r	.705**	.468*	.256	.800**	.713**	.819**	-.046
	sig	**.001**	**.012**	.189	**.001**	**.001**	**.001**	.814
BPQ	Pearson's r	.136	-.250	.065	-.094	-.134	-.075	
	sig	.492	.200	.741	.635	.497	.705	
Non-Technical academic training group								
TAS-DIF	Pearson's r	.482*	.629**	.383	.709**	.609**	.669**	-.145
	sig	**.043**	**.005**	.117	**.001**	**.007**	**.002**	.566
TAS-DDF	Pearson's r	.208	.339	.380	.494*	.275	.361	.100
	sig	.408	.800	.120	**.037**	.270	.141	.619
TAS-EOT	Pearson's r	.200	.603**	.424	.406	.452	.470*	-.200
	sig	.522	**.008**	.079	.094	.060	**.049**	.367
TAS-TOTAL	Pearson's r	.368	.651**	.477*	.670**	.562*	.628**	-.112
	sig	.133	**.003**	**.045**	**.002**	**.015**	**.005**	.657
BPQ	Pearson's r	-.100	-.419	-.177	-.247	-.329	-.317	-.100
	sig	.628	.083	.483	.300	.183	.200	.628

*Significant contrast at the .05 level; **Significant contrast at the .01 level. The ASD group has been clinically diagnosed so the questionnaire was not used in this sample. Univariate ANOVA between technical and non-technical academic training groups. TAS-TOTAL, Alexithymia total score; TAS-DDF, Difficulty in Describing Feelings; TAS-DIF, Difficulty in Identifying Feelings; TAS-EOT, Externally Oriented Thinking; DERS-TOTAL, Difficulties in emotional regulation total score; DERS-NONACCEPTENCE, Nonacceptance of emotional responses; DERS-GOALS, Difficulty engaging in goal-directed behavior: DERS-AWARENESS, Lack of emotional awareness; DERS-CLARITY, Lack of emotional clarity; DERS-CONTROL, Impulse control difficulties; BPQ, Interoception.

alexthimia and interoception in order to explore the differences between groups, the difficulty in describing feelings, difficulty in identifying feelings and externally oriented thinking, which are the subscales of alexithymia and difficulty engaging in goal-directed behavior, Lack of emotional clarity and impulse control difficulties, problem in emotional regulation's subscales; in general, they yielded the same results as their total scoring in differences as well as in associations among them and with interoception.

The results of this study indicated, firstly, that alexithymia was significantly higher in people with ASD compared to the general population groups (both technical and non-technical academic training) with no differences between them. Secondly, regarding interoception, no significant differences were shown between any of the samples, however, the effect size was moderate; therefore,

despite the significance obtained, we can attribute that the expected differences may have not resulted due to the sample size. Thirdly, regarding difficulties in emotional regulation, it was found in the same way as alexithymia, that people with ASD scored significantly higher than both groups of the general population, again, with no differences between them.

This study was based on the hypothesis that people with a technical academic profile (e.g., engineering, technology, etc.) present traits closer to ASD. Thus, in the Autism Spectrum Quotient it was found, as expected, that the technical training group had significantly higher scores than the non-technical academic group (this questionnaire was not used in the ASD population since the diagnosis had been made by an expert clinician). Thus, studying their Pearson's rs, we found in the non-technical training group a significant positive Pearson's r with alexithymia and emotional regulation deficits, but no significant Pearson's r with interoception. However, in the technical training group, the Autism Spectrum Quotient did not correlate significantly with alexithymia, interoception or problems in emotional regulation.

These results show, as hypothesized, that participants with a technical background such as specialties like mathematics, engineering, etc., are closer to ASD traits than participants with a non-technical academic training (Takeuchi et al., 2015). Also, despite only being significant in the non-technical group, alexithymia showed a Pearson's r with ASD. These results point to the fact that this factor may have a connection with ASD traits, something that is actually expected due to its high comorbidity (Poquérusse et al., 2018).

As posed by Bird and Cook in their Alexithymia Hypothesis (Bird & Cook, 2013) we found that, indeed, alexithymia had a strong relationship with emotional regulation. Therefore, based on the principles of this hypothesis we can indicate that alexithymia could be a significant factor in the individual's emotional capabilities in identifying and attributing emotions, pragmatic understanding, and empathy. In addition, our results showed that the Autism Spectrum Quotient had a significant relationship with alexithymia in the non-technical group, therefore, the role of alexithymia may contribute in emotional regulation abilities, and could be closely linked to ASD; thus, these results support the idea that alexithymia could be the factor that interferes with the emotional abilities of these individuals. These results were also shown in other studies in which alexithymia is more related to emotional regulation difficulties than being with ASD (Cai et al., 2018; Costa et al., 2017; Morie et al., 2019; Ryan et al., 2020). On the other hand, based on the literature on the psychological similarity found between individuals with ASD and professionals from technical fields (Takeuchi et al., 2015), it has been found that significant differences appeared in autistic cognition, with higher scores in the technical training group than in the non-technical training group, although both groups maintained non-pathological scores. However, no differences were found in alexithymia, interoception or emotional regulation. This result could be explained from different perspectives; first, the effect size in these three variables between the academic training groups has been shown to be strong, therefore, it can be attributed that there were no significant differences probably because of the number of participants. Second, it is likely that the differences were not significant because both samples were normative (without any diagnosed psychological disorder), therefore, the scores would be from the general population. On the other hand, as explained above, it has been proposed that the problems in emotional regulation could not due to ASD but to a factor unrelated to it; therefore, even if we found significant differences in the Autism Spectrum Quotient, it would not be necessary to find them also in alexithymia, interoception and problems in emotional regulation, since these three variables are independent of ASD, although they are generally shown to be comorbid with it. In fact, there is a recent debate on transdiagnosis, a concept that refers to those characteristics shared among different psychological disorders (Weng et al., 2021). Specifically, it has been found that alexithymia and problems in interoception also appear in anxiety disorders, schizophrenia, psychopathy traits, and type B personality disorders. Thus, the generalization of these two factors provides further evidence of the independence of emotional regulation problems from ASD criteria.

Finally, our results showed significant differences between the ASD sample and the samples with technical and non-technical training in both alexithymia and emotional regulation difficulties. Although no significant differences were found in interoception between groups, we should keep in mind that this variable had a strong Pearson's r with alexithymia and emotional regulation problems, as indicated by the literature (Nicholson et al., 2019; Shah, Hall, et al., 2016). However, interoception has shown a strong negative relationship with alexithymia and positive with problems in emotional regulation in the ASD group, therefore, the results support this hypothesis, although it was limited in the rest of the groups. However, we consider that the fact this result was not fulfilled in the control groups reinforces the role of interoception in ASD, which, although it was not significantly different between groups, it is related to alexithymia and emotional regulation in the ASD group. In addition, the effect size in this variable was moderate, allowing us to explain that the differences were not fulfilled probably due to the lack of sample. On the other hand, we hypothesized that it is possible that the combination of alexithymia and interoception could play an important role in the emotional regulation of people with ASD. This hypothesis could not be tested due to the collinearity of both variables in this study, which prevents us from performing moderation analyses as in other studies where relationships between both variables have been found (Manzoor et al., 2021).

This study is not exempt from limitations, regarding the sample size, even if this study was similar to other studies with ASD populations (Shah, Catmur, et al., 2016), the number of participants was still moderately low, in which differences in sex and age were significant. Although these were controlled finding non-significative in the results, nevertheless, is necessary to further explore the role of these two variables in future research with larger samples to obtain greater statistical power in the results. Moreover, the measurement of interoception has been performed by questionnaire (BPQ), while other studies have used physiological measurements, such as the Heartbeat tracking Task (Manzoor et al., 2021); therefore, the combination of both techniques would be a good alternative to improve the measurement of interoception and thus be able to generalize the results. In addition, the AQ questionnaire was not measured in the ASD sample, although these participants had received their diagnosis clinically, the use of this test in this sample would have given greater manageability of the Autism Spectrum Quotient and an opportunity to study the influence of this variable with alexithymia, interoception and emotional regulation. Moreover, recent studies recommended not to use the total scores of DERS and TAS-20 to measure emotional regulation problems and alexithymia, respectively, in ASD samples (McVey et al., 2022; Williams & Gotham, 2021), fortunately our analysis took these questionnaires subscales into account which, in general, they yielded the same

results, however we suggest for future studies to consider these psychometric limitations. Finally, regarding the Bird and Cook alexithymia hypothesis, to evaluate the role of moderation of interoception between alexithymia and emotional regulation and thus achieve a causal study model, it would have been necessary that alexithymia and interoception to be not correlated, which has prevented the moderation analyses due to the collinearity of the predictor variables.

In conclusion, we found that emotional regulation, long known to be a deficit in ASD, is associated with alexithymia, not ASD *per se*. ASD is commonly comorbid with alexithymia, but it is alexithymia, not ASD, that could be one of the main factors for emotional regulation problems. On the other hand, despite these results, it has not been possible to clarify whether alexithymia and interoception are two completely independent factors or are, in fact, associated with each other. Although some studies have posited them as independent constructs (Manzoor et al., 2021; Palser et al., 2018), others favor their association (Brewer et al., 2016; Shah, Hall, et al., 2016). What we could see is that the found associations in this study, support the possible influence of both variables on the capacity for emotional regulation the ASD group. However, since this study is cross-sectional we cannot conclude the direction of these associations. Nevertheless, we would like to mention that this has been pointed through the literature review conducted; where we found that the particularities of alexithymia and interoception have both a neurological and psychological connection, in which they interfere in the emotional regulation abilities in various psychopathologies, as is the case of ASD. Despite the limitations, we have managed to, at least, contribute as possible evidence to the starting hypotheses; that alexithymia and interoception and emotional regulation are related among them, supporting the idea of the role of alexithymia as a possible main factor of emotional regulation difficulties in individuals with ASD.

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Nour Ben-Hassen: Data curation, data analyses, writing. **Francisco Molins:** Conceptualization, Methodology, Data curation, data analyses. **Dolores Garrote-Petisco:** Methodology, data collection. **Miguel Ángel Serrano:** Conceptualization, Methodology, Writing – review & editing.

Conflict of interest

Authors declare no conflict of interests.

Data availability

Data will be made available on request.

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