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A cross-modal component of alexithymia and its relationship with performance in a social cognition task battery

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ABSTRACT

Background: The personality trait alexithymia describes an altered emotional awareness that is associated with a range of social impairments and constitutes a transdiagnostic risk factor for various psychopathologies. Despite the characteristic interoceptive deficits in alexithymia, it is predominantly assessed via self-reports. This can result in unreliable measurements and arguably contributes to the prevailing uncertainty regarding its components, including constricted imaginal processes and emotional reactivity.
Methods: The current study employed an interview and two validated questionnaires to derive a shared component of multi-modally assessed alexithymia in a German non-clinical sample (n = 78) via prinicipal component analysis. This component was used as a predictor for performance in four behavioural social cognition tasks. The relative importance of this predictor against related variables was assessed via dominance analysis.
Results: The identified component reflected cognitive alexithymia. Higher cognitive alexithymia scores were associated with less affective distress in an ostracizing task. Dominance analysis revealed the dominance of competing autism traits relative to cognitive alexithymia and competing predictors empathy, depression, and anxiety, in predicting affective distress.
Limitations: Emotional reactivity was only assessed via self-report and no implicit measures of alexithymia were employed. Due to the low reliability of the self-report measure, no measure of emotional reactivity could be included in the principal component analysis.
Conclusions: Our results provide compelling evidence that cognitive interoceptive deficits are at the core of alexithymia across assessment modalities. Behavioural data suggest that these deficits result in diminished emotional sensitivity to high-pressure social situations, which may cause a lack of behavioural adaptation.

1. Introduction

The term alexithymia identifies a multidimensional construct that was initially described by cognitive and affective deficits (Sifneos, 1973, 1967). Specifically, alexithymia is characterized by difficulties in identifying and describing one's own emotions, restricted imagination processes, and preoccupation with external events (Krystal, 1983; Sifneos, 1996, 1973). Alexithymia was first described in individuals with mental disorders (Sifneos, 1973, 1967), but is nowadays widely accepted as a dimensional personality trait (Šago and Babić, 2019; Taylor et al., 2016; Taylor and Bagby, 2013). High levels of alexithymia have been related to the development and maintenance of several somatic and mental disorders (Marchesi, 2015; Valdespino et al., 2017), including autism spectrum disorder (Berthoz and Hill, 2005; Hill et al., 2004) or depression (Honkalampi et al., 2000; Li et al., 2015). Importantly, impairments associated with alexithymia also affect non-clinical samples, for whom the interoceptive deficit (Brewer et al., 2016; Tops et al., 2016) is related to higher levels of depressive affect (Honkalampi et al., 2000; Van Der

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Cruijsen et al., 2019), emotional dysregulation (Di Tella et al., 2020), and social impairments (Gerber et al., 2019; Oakley et al., 2020).

Alexithymia is most commonly assessed through self-report questionnaires (Bagby et al., 1994, 1988; Parker et al., 2003; Vorst and Bermond, 2001), and sometimes via interviews (Bagby et al., 2006) or implicit performance-based tests (Subic-Wrana et al., 2001). Notably, self-report instruments may produce inaccurate scores for individuals with elevated levels of alexithymia (Lane et al., 2015; Taylor et al., 2016), who, by definition, show interoceptive deficits (Brewer et al., 2016; Nemiah et al., 1976). The observer-rated Toronto Structured Interview for Alexithymia (TSIA; Bagby et al., 2006) was developed to more objectively assess characteristic impairments in interoceptive skills (Lane et al., 2015, 2000; Marchesi, 2015; Taylor et al., 2016). Yet, few studies thus far employed this laborious approach to measuring alexithymia (Lumley et al., 2007), resulting in sparse evidence on its validity and reliability. Depending on the type of assessment (self--report, interview, or implicit tests), different components of alexithymia were identified (Lichev et al., 2014; Lumley et al., 2005), resulting in an ongoing debate surrounding the underlying components of alexithymia (Gignac et al., 2007; Preece et al., 2017, 2020b). Cognitive emotion processing deficits in alexithymia were found across assessments, but only some measures entailed imaginal processes (Bagby et al., 2006; Vorst and Bermond, 2001). The 'Amsterdam model' subsumed constricted imaginal processes and emotional reactivity under the umbrella term affective emotion processing deficits (Vorst and Bermond, 2001), but accumulating evidence questions the presence of an affective factor in alexithymia (Bekker et al., 2007; Preece et al., 2020b). Other conceptualizations linked a paucity of fantasies more closely to an externally oriented thinking style (Bagby et al., 2006), which jointly describe a cognitive operative thinking style (*pensée operatoire*; Marty and de M'Uzan, 1963) as a defining feature of alexithymia (Nemiah et al., 1976). In addition, the extent to which an impoverished fantasy life should be considered a salient component of alexithymia is under debate (Preece et al., 2017; Sekely et al., 2018; Watters et al., 2016a, 2016b). Despite these mixed and inconclusive findings, studies rarely made use of the pertinent advantages of a multimethod alexithymia assessment (Di Monte et al., 2020; Goerlich, 2018) in understanding its defining components, which may reveal different results.

As a consequence of conceptual uncertainty, controversy exists about the relationship between alexithymia and social cognition. Social cognition is an umbrella term that encompasses dissociable, but interrelated affective processes (Schurz et al., 2020), including sharing of others' emotions (empathy), and cognitive representations of and reasoning about others' thoughts or intentions (theory of mind [ToM]; Kanske et al., 2017; Preckel et al., 2018). Cognitive aspects of alexithymia involve difficulties in describing and identifying feelings (Fonagy et al., 2002; Taylor and Bagby, 2013) and were hitherto consistently linked to deficits in empathy (Grynberg et al., 2010; Moriguchi et al., 2007). In contrast, a link between alexithymia and ToM is under debate (Di Tella et al., 2020; Moriguchi et al., 2006; Taylor et al., 2016). Yet, in assessing these associations with alexithymia, most studies focused on only one aspect of social cognition (e.g. Santiesteban et al. 2015). Since empathy and ToM are distinguishable, but related, disentangling the specific contributions of cognitive and affective aspects of alexithymia (e.g., Albantakis et al. 2020) may reveal a more consistent pattern of associations. Relatedly, closely associated traits such as depression, anxiety (Honkalampi et al., 2000; Van Der Cruijsen et al., 2019) or autistic traits (Hill et al., 2004; Kinnaird et al., 2019) were rarely considered in the relationship between alexithymia and social cognition skills.

In summary, the available evidence on the defining features of alexithymia is mixed and dependent on assessment methods. The current study aimed to shed light on the components of alexithymia and their relation to various facets of social cognition. Principal component analysis (PCA) was used to determine an optimal set of alexithymia components from three well-established assessment instruments: the TSIA, the Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994; Parker et al., 2003; Taylor et al., 2003), and the Bermond-Vorst Alexithymia Questionnaire (BVAQ; Vorst and Bermond, 2001). We expected that components would reflect a method bias (i.e., self-report or interview-based; Lichev et al., 2014; Lumley et al., 2005; Podsakoff et al., 2003) and would differentially mirror cognitive and, if applicable, affective emotion processing deficits. We scrutinized how the identified components account for impairments in multiple domains of social cognition. The relative contribution of alexithymia components respective to competing predictor variables was disentangled via dominance analysis, an extension of multiple regression analysis (Azen and Budescu, 2003; Budescu, 1993) that allows to rank-order each predictor's contribution. To the best of our knowledge, only one study (Shah et al., 2019) employed dominance analysis as a statistical tool to compare the importance of alexithymia relative to autism in predicting social cognition in the general population. The current study expands this sparse literature by comparing different alexithymia components, including a battery of validated *behavioural* social cognition measures, and considering *pertinent* associated traits. We hypothesized that cognitive components of alexithymia would predict worse performance in ToM tasks (the representation of other people's cognitive mental states and visual perspective taking). We expected affective components of alexithymia, if present, to predict worse performance in tasks related to empathic processes (the recognition of other people's affective states) and alterations in affective distress. All hypotheses were preregistered; https://osf.io/tfjru/.

2. Methods

2.1. Participants and procedure

This study is part of a magnetic resonance imaging project that assesses neural correlates of alexithymia, empathy, and ToM in the general population. Inclusion criteria were thus contingent on magnet resonance imaging contraindications. Accordingly, exclusion criteria were age below 18, pregnancy, current or past mental or neurological disorders, current or past drug or alcohol abuse, and previous participation in a cyberball paradigm. Participants were recruited via fliers and an inhouse data base. The study was approved by the Ethics Committee of the University of Leipzig (140/18-ek) and written informed consent was obtained prior to participation. All participants were financially compensated for their participation. Our sample included 78 (38 men, 40 women) neurotypical volunteers (Table 1). Valid performance scores from social cognition tasks were available in a subset of $n = 54$ to $n = 68$ participants (supplementary Tables S3 and S4).

2.2. Alexithymia assessment

TSIA. The TSIA (Bagby et al., 2006) comprises 24 items covering the facets (1) difficulty identifying feelings (DIF), (2) difficulty describing feelings to others (DDF), (3) externally oriented thinking (EOT), and (4) imaginal processes (IMP). The interviewer (a trained research assistant) scored all items along a 3-point continuum on the degree of the frequency, presence, or expression of a characteristic. All interviews were

Table 1
Sample description.

	M (*SD*)	*N* (%)	Range
Age (years)	28.73 (4.21)[a]		20.30 – 39.22
Sex, male		38 (49%)	
Marital status			
Married/in a relationship		21 (27%)	
Never-married		57 (73%)	
Educational level (years)	17.70 (2.97)[b]		8.50 - 25.00

[a] Welch's *t*-test for the difference between sexes, $t(75.97) = 0.31$, $p = .756$.
[b] Welch's *t*-test for the difference between sexes, $t(74.99) = 0.46$, $p = .646$.

audio recorded and reviewed by an additional coder who was blind to the scores made by the interviewer and to participant's questionnaire scores. A total score and facet scores are derived, with higher scores indicating a higher degree of alexithymia.

TAS-20. The TAS-20 is a questionnaire (Bagby et al., 1994; Taylor et al., 1992, 1985) that comprises 20 items covering (1) DDF, (2) DIF and (3) EOT (Taylor et al., 1985). Items are answered on a 5-point Likert scale ranging from 1 = *strongly disagree* to 5 = *strongly agree*. While DDF, DIF, and EOT represent theory-based facets of alexithymia, they only adequately reflect the alexithymia construct when combined into a single score (Bagby et al., 2007; Carnovale et al., 2021), i.e., the TAS-20 total score. TAS-20 total scores range from 20 to 100, with higher scores indicating a higher degree of alexithymia.

BVAQ. The 40-item BVAQ (Vorst and Bermond, 2001) was developed specifically to capture cognitive and affective dimensions of alexithymia. Items are answered on a 5-point Likert scale ranging from 1 = *this in no way applies* to 5 = *this definitely applies*. The BVAQ comprises the facets (1) Verbalizing one's own emotional states, (2) Identifying the nature of one's own emotions, (3) Analysing one's own emotional states, (4) Fantasizing, the degree to which someone is inclined to imagine or daydream, and (5) Emotionalizing, the degree to which someone is emotionally aroused by emotion-inducing events. The facets Verbalizing, Identifying, and Analyzing assess the cognitive dimension of alexithymia and the facets Emotionalizing and Fantasizing assess the affective dimension of alexithymia. Total scores range from 0 to 160, with higher values indicating higher levels of alexithymia.

2.3. Additional variables

To explore whether components of alexithymia capture unique variance in social cognition beyond related psychosocial constructs, we considered the following competing predictors in dominance analyses: empathy, autism traits, depression, and anxiety. Details on the properties of these competing predictors are outlined in the supplementary methods section.

2.3.1. Behavioral tasks for various domains of social cognition

Behavioural tasks were administered to address several hypotheses as part of a wider investigation. Since the current study aimed to investigate the relationship between alexithymia and a series of social cognition outcomes (see our preregistration), we examined only the most common outcome measures per task pertinent to the current research question. Future investigations based on the same tasks will compute differential outcomes measures, in line with the specific research questions.

2.3.2. Recognition of other people's affective states: reading the mind in the eyes test

The Reading the Mind in the Eyes Test (RMET) is a widely used measure of emotion recognition that assesses an individuals' ability to read the other person's thoughts, intentions, and feelings through facial expressions (Baron-Cohen et al., 1997). Based on static images depicting the eye region of the face, participants are asked to choose one of four adjectives that best describes the feeling expressed on the picture. Our version of this task included a control condition during which participants had to estimate the age and sex of the individual displayed on the picture (Baron-Cohen et al., 2001a; Martin et al., 2021). Participants' RMET score was calculated as the total number of correct responses in the experimental minus the control condition. Higher scores indicate a greater ability to recognize other peoples' affective states.

2.3.3. Representation of other people's cognitive mental states: false belief task

The False Belief task (Saxe and Kanwisher, 2003) is a measure of cognitive ToM which is typically delivered in a story format and requires participants to make inferences about a character's true and false beliefs on a state of affairs. Our version consisted of 30 stories in two conditions, false belief (FB) and false photograph. In the FB condition, participants are presented short scenarios that describe a character's action based on his/her FB and participants are required to infer the character's mental state. In the false photograph condition, stories describe how a picture is taken of a scene, the scene is changed, and the participant is asked what the picture depicts. Participants' FB score was calculated as the difference between correct responses in the FB and false photo condition, with higher scores reflecting a better performance.

2.3.4. Visual perspective taking: director's task

The Director's Task was employed to measure participants' ability for (visual) perspective taking. Our adapted version of the director's task (Dumontheil et al., 2010; Keysar et al., 2000) comprised a Director Present and a Director Absent control condition. Stimuli consisted of a set of shelves in a 4 × 4 grid, pre-recorded sound files for the instructions, and cartoon figures representing directors for the Director Present condition. Participants followed instructions given by the director to move objects within a grid of shelves. For the present study, only three-object trials were considered, in which performance depended on participants' ability to take the director's perspective: In the Director Present condition, the correct object was identified by whether the director providing the instruction (identified as male or female by his/her voice) was standing at the front or back of the shelves. During these trials, participants had to consider the director's viewpoint (which differed from their own viewpoint on half of the trials) to avoid selecting the irrelevant 'distractor' object during all trials, despite the director's perspective was different from that of the participant in only half of the trial. The Director Absent trials did not involve perspective taking (i.e., representing a different viewpoint), as instructions were based on a simple rule. Performance was quantified as the difference in accuracy and reaction time between Director Present and Director Absent conditions.

2.3.5. Affective distress of social rejection: cyberball game

The Cyberball task was included as a measure of stress elicited by social exclusion or social performance pressure. We adapted and extended the classic Cyberball task, during which participants play an online ball-tossing game apparently with two other partners (see Wagels et al. 2017; see also Vrtička et al., 2020). There are no real other players and participants instead play with computer-guided avatars. The Cyberball task in this study included two main phases: (1) a free game, in which the players freely pass the ball between each other, and (2) a performance game, in which throws earn money for the group of players depending on the speed of ball tossing, thus inducing social performance pressure (Wagels et al., 2017). Our adapted version included four conditions: (1) implicit exclusion, in which participants were told that they are not yet connected to the game even though they were able to see the other players tossing the ball, (2) inclusion, in which the two other partners play with the participants, (3) exclusion, in which the other players throw the ball only to each other, excluding the participant, and (4) re-inclusion, in which all players once more receive the ball equally often. After each phase, participants were asked to report their stress and wellbeing on a 9-point Likert scale. The stress- and wellbeing-rating in the first inclusion phase of the performance game and in the exclusion phase in the free game were assessed as dependent variables. Higher stress- and lower wellbeing-scores in the performance game indicate greater sensitivity to performance pressure in a social context. Higher stress- and lower wellbeing-scores in the free game indicate greater sensitivity to social exclusion.

2.4. Statistical analysis

All statistical analyses were carried out with R version 3.6.0 (R Core Team, 2019). Outliers were defined as values > 3 *SD* above or below the sample mean; if model checks suggested evidence for influential cases, these outliers were winsorized to the respective boundary ($n = 2$ tasks with 1 participant each, supplemental material).

2.4.1. Interrater and internal reliability for the TSIA

Interrater reliability at the individual TSIA item level was assessed with Cohen's weighted kappa coefficient (Cohen, 1960) and Spearman's rank correlation coefficient and with two-way mixed intraclass correlation coefficients at the total score and facet level. Internal reliability and item-to-scale homogeneity of all alexithymia questionnaires were assessed via Cronbach's alpha and average inter-item correlations.

2.4.2. Principal component analysis

To capture maximum variability across measures with the minimum number of uncorrelated variables, we performed a PCA on the $n = 8$ alexithymia facet scores derived from the TSIA and BVAQ and the TAS-20 total scores (note that the BVAQ Emotionalizing scale was excluded from the PCA due to its low reliability, see Results). All facet scores and the TAS-20 total score were standardized prior to submitting them to the PCA. The choice to use the TAS-20 total score but subscale scores for the TSIA and BVAQ was based on the developers' recommendations to use the TAS-20 total score only and accumulating evidence casting into doubt the validity of using the TAS-20 facet scores (Bagby et al., 2007; Carnovale et al., 2021). PCAs were performed on the facet scores as the observed variables rather than individual item scores (Leising et al., 2009; Lichev et al., 2014) to follow recommendations of a minimum subjects-to-variable ratio of 5 (MacCallum et al., 1999), resulting in a subjects-to-variables ratio of 9.75. We employed a traditional parallel analysis (Lim and Jahng, 2019) and the scree plot method (Cattell, 1966) to determine the number of components. In parallel analysis, eigenvalues are extracted from random data sets that parallel the actual dataset regarding the number of participants and variables. Then, the eigenvalues derived from the actual data are compared to the eigenvalues of the random data and retained as long as the *i*th component of the actual data exceeds the *i*th component of randomly generated data (eigenvalues > 1). The PCA was carried out with promax rotation to account for correlated components by extracting the previously determined fixed number of components. Component loadings ≥. 40 were considered meaningful (Stevens, 2002). A bootstrapping procedure was performed on the PCA to obtain stable loadings of facet scores (supplementary methods, supplementary Table S2 and supplementary Figure S2). Bootstrapping involves resampling a data set with replacement n number of times and calculating a desired statistic on the resampled data sets, which allows for the calculation of confidence intervals and an average statistics of interest over all resampled data sets to simulate having a larger dataset (Fisher et al., 2016).

2.4.3. Multiple regression and dominance analysis

Multiple regression analyses were run to assess which alexithymia components were significant predictors for the different measures of social cognition. In a second step, we examined which components remained significant predictors after accounting for pre-selected pre-registered competing predictors (empathy, autistic traits, depression, anxiety). The predictors were entered into the regression model according to the following schema: model 1, sociodemographic variables (age, sex); model 2, model 1 plus alexithymia components derived from the PCA; model 3, model 2 plus competing predictors.

Dominance analysis (Azen and Budescu, 2003; Budescu, 1993) was used to deal with presumably highly correlated predictors (Lichev et al., 2014; Shah et al., 2016), a method that estimates the R^2-values of all possible combinations of predictors and measures by doing pairwise comparisons of all predictors in the model as they relate to an outcome variable. The incremental validity of each predictor across all possible subset regression models was used to calculate general dominance weights, which sum to the overall model R^2 and thus reflect the relative importance of each predictor to the criterion.

3. Results

3.1. Interrater and internal reliability for the TSIA

In the sample of 78 interviews, the ICC reliability estimates were 0.90 ($p < .001$) for the TSIA total score, 0.82 ($p < .001$) for the DDF facet, 0.88 ($p < .001$) for the DIF facet, 0.92 for the EOT facet ($p < .001$), and 0.88 ($p < .001$) for the IMP facet, which was interpreted as a good-excellent interrater reliability for the total scores and all facets. At the item level, percentage of agreement between interviewers was 76.3%, the chance-corrected Cohen's weighted kappa was $\kappa = 0.601$, $p < .001$, and the correlation between both interviewers' ratings was $r_S = 0.64$, $p < .001$, indicating substantial agreement.

3.2. Descriptive statistics

The internal consistencies and inter-item correlations largely corresponded to the recommended standards (supplementary Table S1 and Fig. S1), indicating adequate item-to-scale homogeneity for the alexithymia measures. However, Cronbach's alpha was questionable for the TSIA DDF facet, inacceptable for the TAS EOT facet, and fairly low for the BVAQ Emotionalizing facet. Due to its low reliability, the Emotionalizing facet was excluded from the PCA.

3.3. Principal component analysis

The results of the parallel analysis and the scree test based on the facet scores suggested the extraction of one component (Fig. 1A). The derived component was comprised of all scales except for the BVAQ Fantasizing facet, and with relatively weaker loadings of the TSIA IMP facet. This factor was labelled *Cognitive Alexithymia*. This component explained 43% of the variance. The promax rotated solution of the one-component model is presented in Fig. 1B.

3.4. Descriptive statistics and correlations with social cognition measures

Scores for alexithymia components, competing predictor variables (i.e., autistic traits, empathy, anxiety, and depression) and social cognition measures all displayed adequate variance in the sample. Correlations and all scores are presented in supplemental Table S3 and Fig. S3.

3.5. Multiple regression analyses

Table 2 gives an overview of all models. The results are summarized in the text. In all regression analyses, the statistical factor of tolerance and variance inflation factors showed no interfering interactions between the variables.

For the sensitivity to social exclusion (operationalized in the CG free game), entering competing predictor variables significantly increased R^2 by 18.33% for the wellbeing-ratings, but the model was only marginally significant, $F(8, 59) = 1.99$, $p = .064$, and none of the predictors reached significance (all $p > .116$). Regarding the sensitivity to social performance pressure (operationalized in the CG performance game), entering competing predictor variables significantly increased R^2 by 22.38% for the stress-ratings and by 22.34% for the wellbeing-ratings. The model for the stress-ratings, $F(8, 59) = 3.18$, $p = .005$, was significant, with alexithymia, $\beta = -0.41$, $p = .012$, autism traits, $\beta = 0.48$, $p = .001$, and age, $\beta = -0.27$, $p = .022$, as significant predictors. Likewise, the model for the wellbeing-ratings, $F(8, 59) = 3.42$, $p = .003$, reached significance, and age, $\beta = 0.24$, $p = .039$, and trait anxiety, $\beta = -0.28$, $p = .057$, emerged as (marginally) significant predictors.

No significant associations emerged in models for the recognition of other people's affective states (operationalized in the RMET score), the representation of other people's cognitive mental states (operationalized in the FB score), for visual perspective taking (operationalized in the DT score and RT), and for the sensitivity to social exclusion

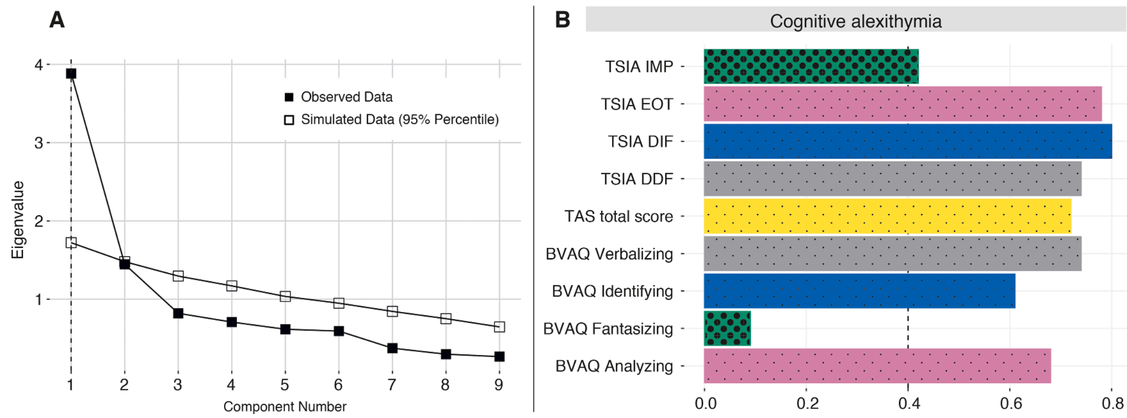

Fig. 1. *Results of the Principal Component Analysis,* Panel A: Scree plot indicating the number of components to retain. Panel B: Loadings of the two-component solution (oblique promax rotation). BVAQ = Bermond-Vorst Alexithymia Questionnaire, DDF = Difficulty Describing Feelings, DIF = Difficulty Identifying Feelings, EOT = Externally Oriented Thinking, IMP = Imaginal Processes, TAS- = 20-item Toronto Alexithymia Scale, TSIA = Toronto Structured Interview for Alexithymia. The vertical dashed line indicates component loadings ≥ .40, which were considered meaningful (Stevens, 2002). Similar colours indicate scales intended to measure the same construct. Filling with large dots indicates facets intended to measure affective, filling with small dots indicates facets intended to measure cognitive components.

Table 2
Overview of regression models for all social cognition measures.

Outcome Measure	Model	Predictors	R^2 (%)	Adj R^2(%)	*F* change	Sig. *F* change
RMET[a]	1	Age, sex	6.29	2.68	$F(2, 52) = 1.74$	.185
	2	Age, Sex, Alexithymia	7.26	1.81	$F(1, 52) = 0.54$	.466
	3	Age, Sex, Alexithymia, AQ, IRI, EQ, BDI-II score, STAI-T score	23.68	10.41	$F(5, 46) = 1.98$	.100
FB score	1	Age, sex	5.12	1.47	$F(2, 52) = 2.40$	.255
	2	Age, Sex, Alexithymia	5.34	−0.02	$F(1, 50) = 0.12$	.730
	3	Age, Sex, Alexithymia, AQ, IRI, EQ, BDI-II score, STAI-T score	24.36	11.21	$F(5, 46) = 2.31$	.059
DT score[a]	1	Age, sex	0.00	−3.89	$F(2, 51) = 0.01$	.994
	2	Age, Sex, Alexithymia	6.70	1.11	$F(1, 50) = 3.58$	.064
	3	Age, Sex, Alexithymia, AQ, IRI, EQ, BDI-II score, STAI-T score	24.92	11.8	$F(5, 45) = 2.18$	.072
DT reaction time	1	Age, sex	4.55	0.81	$F(2, 51) = 1.22$	.305
	2	Age, Sex, Alexithymia	6.33	−0.71	$F1, 50) = 0.95$	.335
	3	Age, Sex, Alexithymia, AQ, IRI, EQ, BDI-II score, STAI-T score	7.80	−8.60	$F(5, 45) = 0.14$	.981
CG Stress FG	1	Age, sex	0.75	−2.31	$F(2, 65) = 0.25$	.782
	2	Age, Sex, Alexithymia	1.68	−2.93	$F(1, 64) = 0.60$	.440
	3	Age, Sex, Alexithymia, AQ, IRI, EQ, BDI-II score, STAI-T score	12.22	0.32	$F(5, 59) = 1.42$	.231
CG Wellbeing FG	1	Age, sex	0.01	−0.02	$F(2, 65) = 1.18$	.834
	2	Age, Sex, Alexithymia	2.90	−1.65	$F(1, 64) = 1.54$	.219
	3	Age, Sex, Alexithymia, AQ, IRI, EQ, BDI-II score, STAI-T score	21.23	10.55	$F(5, 59) = 2.75$	.027*
CG Stress PG	1	Age, sex	5.50	2.59	$F(2, 65) = 1.89$	.159
	2	Age, Sex, Alexithymia	7.72	3.40	$F(1, 64) = 1.54$	.219
	3	Age, Sex, Alexithymia, AQ, IRI, EQ, BDI-II score, STAI-T score	30.10	20.62	$F(5, 59) = 3.78$	.005**
CG Wellbeing PG	1	Age, sex	8.78	5.97	$F(2, 65) = 3.13$	.051
	2	Age, Sex, Alexithymia	9.35	5.10	$F(1, 64) = 0.40$	.528
	3	Age, Sex, Alexithymia, AQ, IRI, EQ, BDI-II score, STAI-T score	31.69	22.43	$F(5, 64) = 3.86$	.004**

AQ = Autism-Spectrum Quotient, BDI-II = Beck Depression Inventory – Second Edition, CG = Cyberball Game, DT = Director's Task, EQ = Empathy Quotient, FB = False Belief Task, FG = Free Game, IRI = Interpersonal Reactivity Index, RMET = Reading the Mind in the Eyes Test, PG = Performance Game, STAI-T= State-Trait Anxiety Inventory – Trait.

[*] $p < .05$.

[**] $p < .01$.

[a] $n = 1$ participant was identified as an influential case and winsorized.

(operationalized in the CG free game). Neither entering alexithymia components nor competing predictor variables significantly increased R^2 for these outcome measures (Table 2).

3.6. Dominance analyses

Multicollinearity was a concern: all variables were significantly correlated with the outcome measures (supplementary Figure S3). Consequently, dominance analyses were conducted to rank order by importance the predictors of each criterion. Fig. 2 depicts the general dominance weights for all models and social cognition measures (note that these weights sum up to total R^2 for each model). In detail, we only reported the results of for the significant models, but all models are shown in Fig. 2.

Regarding the sensitivity to social performance pressure, dominance analyses showed that autism traits dominated alexithymia and all other predictors of the stress-ratings in the performance game (Fig. 2, Model 3), and that trait anxiety dominated all other predictors of the wellbeing-ratings in the CG performance game (Fig. 2, Model 3).

4. Discussion

The present study is the first to derive shared components of alexithymia across two well-established questionnaires and one interview in a non-clinical sample. A one-factor solution that reflected cognitive

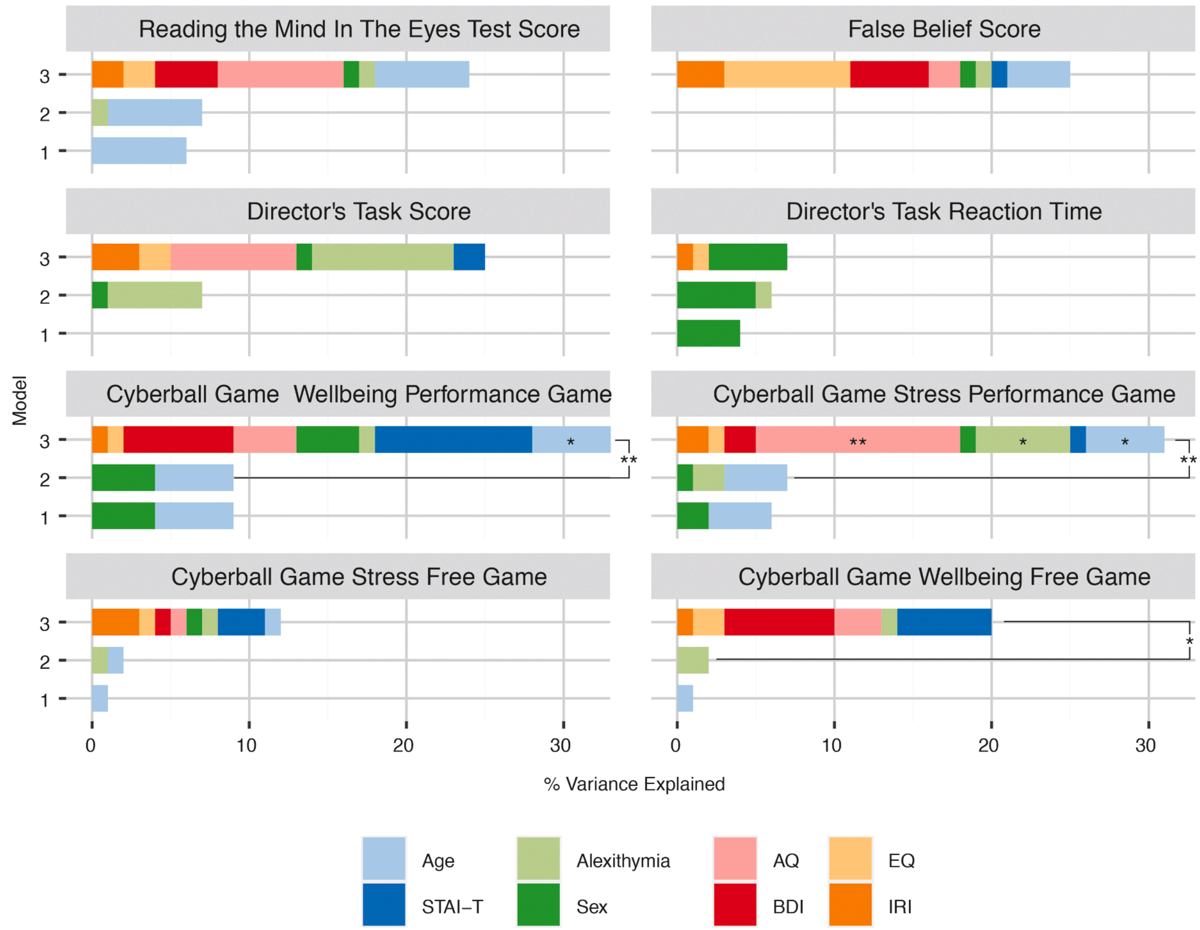

Fig. 2. *Dominance Analysis Results for all Regression Models,* Bars for each predictor indicate general dominance weights, with higher values indicating the more important predictor.

alexithymia best represented our data. We investigated the relationship of this component with behavioural performance in four social cognition tasks. Cognitive alexithymia was a significant predictor of lower affective distress, specifically, less sensitivity to social performance pressure. For the identified associations with affective distress, we compared the relative importance of alexithymia and the competing variables autism traits, empathy, depression, and anxiety, as predictors via dominance analysis. Cognitive alexithymia dominated all variables except autism traits as predictor of less affective distress. Importantly, affective distress was predicted positively by autism traits, but negatively by cognitive alexithymia. This suggests that although impaired social functioning relates to alexithymia and autistic traits, both may operate at different stages in the modulation of social interactions. The characteristic interoceptive deficit in alexithymia may serve a protective function against negative emotional experiences, but likewise prevent behavioural adaptations according to the social context and may thus not always be adaptive. The lack of behavioural adaptations accompanying autism traits, in contrast, may stem from poor communication skills required to communicate heightened psychological distress.

Previous research identified a *pensée operatoire*, describing an externally oriented, concrete thinking style with reduced emotionality (Franz et al., 2008; Gignac et al., 2007), and *anomia*, a lack of words for emotions, as defining features of alexithymia (Marty and de M'Uzan, 1963; Nemiah and Sifneos, 1970). Our one-component solution uniquely corroborates this concept based on a cross-modal assessment. The three well-established alexithymia measures used in this study all include difficulties in identifying and verbalizing feelings as well as an externally oriented thinking style. Considering our loadings on the shared alexithymia component, our findings confirm the key role of anomia in alexithymia (Sekely et al., 2018; Watters et al., 2016b, 2016a).

However, our findings show weaker or no contributions of an impoverished fantasy life to the overall construct of alexithymia, in line with previous mixed and inconclusive evidence (Bagby et al., 2009; Preece et al., 2017, 2020b). Initially included in all measures, the fantasizing scale was removed from the TAS-20 after revisions (Taylor et al., 1992) or from the TSIA upon development of a short form (Sekely et al., 2018). Indeed, echoing previous findings (Bagby et al., 2006; Caretti et al., 2011), the TSIA scale assessing imaginal processes did not correlate significantly with the TAS-20 total score in our study (supplementary Table S1). Positive correlations between all TSIA scales in our and previous studies (Bagby et al., 2006; Caretti et al., 2011; Grabe et al., 2009) may thus reflect a shared method bias (Podsakoff et al., 2003). This interpretation is consistent with the finding of relatively high loadings of all TSIA scales on the alexithymia component, yet with the weakest loadings for the scale assessing imaginal processes (which were only marginally above the criterion upon which loadings were considered meaningful; Stevens, 2002). Relatedly, associations between the TSIA and especially the BVAQ scales assessing fantasy and the other TSIA and BVAQ scales and the TAS-20 score were modest and mostly non-significant (supplementary Figure S3), in accordance with previous studies (Preece et al., 2017; Rosenberg et al., 2016; Watters et al., 2016a, 2016b) and with the finding of preserved emotional imagination capabilities in neurotypical individuals with high alexithymia (Bausch et al., 2011). Overall, our findings thereby support recent conceptualizations of alexithymia being comprised of difficulty identifying and describing feelings and an externally oriented thinking style (Bagby et al., 1994; Preece et al., 2020a, 2017), but without fantasizing as a significant component of alexithymia (Sekely et al., 2018). We find that cognitive interoceptive deficits in alexithymia are only related to reduced affective distress in situations with high social pressure, but not to any of the other domains.

Our finding that cognitive alexithymia predicts less sensitivity to high-pressure social situation complements a neuroimaging study by Chester and colleagues, who reported a relationship between difficulties in identifying feelings and reduced activation in the dorsal anterior cingulate during rejection in the Cyberball game (Chester et al., 2015). The more difficulties individuals experienced in identifying feelings, the less activity in the dorsal anterior cingulate, a neural correlate of distress, was observed. This reduced activity mediated the relationship between higher difficulties in identifying feelings and more daily social rejection experiences. The authors argued that high-alexithymic individuals still understand that they are being rejected, but the realization of exclusion remains unaffected by aversive distress. Aversive distress, however, potentially prevents exclusion (Chester et al., 2015) by giving individuals the opportunity to adapt their social behavior in accordance with experienced emotional signals (Goerlich, 2018). The lack of stressful emotional experience in alexithymia may thus prevent behavioural adaptations promoting successful social interactions, which can also explain the association between alexithymia and reduced social interactions (Gerber et al., 2019). Autistic traits were, in contrast, associated with higher affective distress. Poorer communication skills associated with autistic traits (Baron-Cohen et al., 2001b) may be accounted for by elevated levels of alexithymia, i.e., difficulties in verbalizing one's own emotions (Oakley et al., 2020). Thus, both the inability to perceive (Oakley et al., 2020) and to adequately communicate high stress levels in demanding situations may foster social anxiety (Albantakis et al., 2020; Hintzen et al., 2010) in people with high autism traits. This line of argumentation is supported by the finding that individuals with autism spectrum disorder differ from neurotypical individuals in the quality (Baron-Cohen and Wheelwright, 2003; Hintzen et al., 2010), but not the quantity of social interactions (Gerber et al., 2019; Hintzen et al., 2010).

5. Limitations

Overall, this study makes an important step towards a better understanding of social cognition deficits associated with alexithymia. Major strengths of this study include the use of the observer-rated TSIA and the two most common questionnaires TAS-20 and BVAQ for alexithymia assessment, the assessment of various aspects of social cognition with validated behavioural tasks, and the careful selection of control variables. Nonetheless, our study has several limitations that merit discussion. Considering the high loadings of all TSIA scales on our component, this component may not only reflect different aspects of alexithymia but also a method response bias (Lumley et al., 2005) for interviews versus self-report measures. Relatedly, previous studies distinguished explicitly (and thus subjective, e.g., interview or self-report) from implicitly measured (e.g., performance tasks) alexithymia (Lichev et al., 2014; Lumley et al., 2007, 2005). Implicit measures are believed to uniquely capture dimensions of alexithymia that cannot be consciously accessed (Lane et al., 2015, 1990; Lumley et al., 2005), especially imaginal processes and emotional reactivity. Accordingly, weaker evidence for the fantasizing scales does not necessarily question the extent to which fantasizing forms a salient component of alexithymia, but may instead arise from the specific item content (Watters et al., 2016b). Both the TSIA and the BVAQ items focus on the presence or absence of imaginal processes, but do not assess the content of imaginal processes (including emotionality and vividness), which in turn may be better accessible with implicit performance-based tests (Tibon et al., 2005) and provide information on associated normopathy (MacDougall, 1989).

Furthermore, the only emotional reactivity measure included in this study was the BVAQ emotionalizing scale, which was not subjected to the PCA due to its poor reliability (see also Müller et al. 2004). This poor reliability potentially results from the lacking distinction between negative and positive emotional reactivity (Preece et al., 2017; Sekely et al., 2018), thereby precluding inferences regarding the inclusion of an affective factor in alexithymia. Clearly, future research is needed to consider emotional reactivity as well as to distinguish between positive and negative emotional reactivity (Becerra et al., 2019). Ideally, future studies should not only assess the presence, but also the content of participants' fantasies. Regarding social cognition task selection, weak relationships between visual perspective taking and other social cognition measures could be seen as evidence against the validity of this task, echoing earlier suggestions to consider the director's task as a task of selective attention rather than ToM (Rubio-Fernández, 2017). Lastly, our study was conducted in a non-clinical, highly educated sample. Future research should investigate whether these results generalize to clinical samples whose alexithymia levels significantly exceed those observed in neurotypical samples (Oakley et al., 2020, 2016). Nonetheless, the robustness of our results for neurotypical samples is strengthened by supplementary analyses.

6. Conclusions

In synthesis, our results suggest that alexithymia encompasses cognitive deficits in emotional awareness and a reality-based, pragmatic thinking style. These findings support the assumption that the scarcity of fantasies and daydreams may be considered peripheral features of alexithymia, if at all relevant. Our findings further demonstrate that cognitive interoceptive deficits in alexithymia are associated with reduced affective distress. If we accordingly consider difficulties in affect awareness as a key feature of alexithymia, individuals with elevated levels of alexithymia may benefit from interoception trainings. These trainings could foster individual's abilities to identify and describe emotions, which may help in identifying emotional overwhelm and in selecting appropriate emotion regulation strategies (Farrell and Shaw, 1994). Thus, these trainings may enhance intentions of and ultimately improve interpersonal communication and associated behavioural adaptations to the situational requirements.

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CRediT authorship contribution statement

Sarah A. Rösch: Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Lara M.C. Puhlmann:** Methodology, Software, Data curation, Validation, Investigation, Writing – review & editing, Project administration. **Katrin Preckel:** Conceptualization, Methodology, Software, Validation, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Supplementary materials

The following are available in the online version, at doi:10.1016/j.jad.2021.11.012: Supplementary Methods, Supplementary Results, Supplementary Fig. S1: Means and Estimated Correlations for all Measures of Alexithymia; Supplementary Fig. S2: Bootstrapping Results; Supplementary Fig. S3: Correlations between Alexithymia Scores, Competing Predictor Variables, and Social Outcome Measures; Supplementary Table S1: Descriptive Statistics: Means, Standard Deviations, Ranges, and Internal Consistencies for the Measures of Alexithymia; Supplementary Table S2: Loadings, Standardized Loadings, and 95% Confidence Intervals for the First Principal Component, Supplementary Table S3: Scores for Alexithymia Components, Competing Predictor Variables, and Social Outcome Measures; Supplementary Table S4: Available N and Missing Data in Social Cognition Tasks.

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