Published in final edited form as:

J Affect Disord. 2019 April 15; 249: 253–261. doi:10.1016/j.jad.2019.02.038.

Alexithymia is associated with neural reactivity to masked emotional faces in adolescents who self-harm

Lauren A. Demers^{a,*}, Melinda Westlund Schreiner^b, Ruskin H. Hunt^a, Bryon A. Mueller^c, Bonnie Klimes-Dougan^b, Kathleen M. Thomas^a, Kathryn R. Cullen^c

^aInstitute of Child Development, University of Minnesota College of Education and Human Development, Minneapolis, MN 55455, USA

^bDepartment of Psychology, University of Minnesota College of Liberal Arts, Minneapolis, MN 55455, USA

^cDepartment of Psychiatry, University of Minnesota Medical School, Minneapolis, MN 55455, USA

Abstract

Background: Non-suicidal self-injury (NSSI) is a major, trans-diagnostic mental health problem among adolescents. Alexithymia has been identified as a developmental risk factor for NSSI. Research on how alexithymia relates to the neurobiology of automatic emotion processing is only beginning to emerge. This study evaluates the relationship between alexithymic features and neural responses to automatic processing of emotional content in adolescents with NSSI.

Methods: 25 female adolescents (ages 13–21) with a history of repeated engagement in NSSI completed the Toronto Alexithymia Scale and the Difficulties with Emotion Regulation Scale and underwent functional magnetic resonance imaging (fMRI) during a task in which participants were exposed to masked emotions.

Results: One facet of alexithymia, limited internal emotion awareness or externally-oriented thinking (EOT), was related to differential reactivity to masked emotional faces in clusters in the right supramarginal gyrus and right inferior frontal gyrus. Follow-up assessment of regional reactivity revealed that greater EOT is associated with lower activation to masked happy faces but higher activation to masked fearful faces. Other facets of alexithymia did not show relationships with reactivity to masked emotional faces.

Limitations: This is a cross-sectional and small sample that only includes females, which may attenuate generalizability of findings.

*Corresponding author. demer048@umn.edu (L.A. Demers).

Contributors: Study conception and design: Kathryn R. Cullen, Bonnie Klimes-Dougan, Kathleen M. Thomas.

Acquisition of data: Melinda Westlund Schreiner, Bryon A. Mueller.

Analysis and interpretation of data: Lauren A. Demers, Melinda Westlund Schreiner, Ruskin H. Hunt, Bryon A. Mueller, Bonnie Klimes-Dougan, Kathleen M. Thomas, Kathryn R. Cullen.

Drafting of manuscript: Lauren A. Demers.

Critical revision: Lauren A. Demers, Melinda Westlund Schreiner, Bonnie Klimes-Dougan, Kathleen M. Thomas, Kathryn R. Cullen.

Disclosures/conflicts of interest

All authors declare that they have no conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jad.2019.02.038.

Conclusions: We report neural correlates of multiple facets of alexithymia in adolescents with NSSI. Among adolescents who self-harm, those with higher levels of EOT may be less alert to subtle positively-valenced emotion cues. For this subset of adolescents with NSSI, interventions designed to enhance mental representation of emotional responses and attention to positive emotions may be appropriate.

Keywords

Non-suicidal self-injury (NSSI); Alexithymia; Masked faces; fMRI

1. Introduction

Between 13% of adolescents engage in self-injurious behaviors (Jacobson and Gould 2007; Lloyd-Richardson et al., 2007). Of these, 6.7% of adolescents report repetitive non-suicidal self-injury (NSSI) according to the DSM-5 criteria listed in the “Conditions for Further Study” (Zetterqvist et al., 2013; American Psychiatric Association, 2013). NSSI involves the intentional, direct destruction of one’s own body tissue without suicidal intent in a manner that is not culturally sanctioned (Nock, 2009). NSSI can take the form of cutting or carving the skin, scratching, burning, head banging, self-hitting, or ingesting potentially hazardous material (Black and Mildred, 2016). Self-injurious behavior is observed in the context of depression, borderline personality disorder and various other psychiatric diagnoses (Glenn and Klonsky, 2013; In-Albon et al., 2013), but may not be associated with a diagnosis, and is known to be a risk factor for suicidality (Klonsky et al., 2013; Tuisku et al., 2014). There are a number of purported psychological functions of NSSI that primarily involve attenuating or avoiding negative emotional/cognitive states in the context of challenging interpersonal interactions (Bentley et al., 2014).

One risk factor for the development of NSSI is alexithymia (Fliege et al., 2009; Lüdtke et al., 2016). Alexithymia refers to the impaired ability to attend to and verbally label emotions via ongoing introspection (Sifneos, 1973). Alexithymia is most commonly assessed by the Toronto Alexithymia Scale – 20 items (TAS-20), which has three subscales or facets, which reflect difficulty identifying (Difficulty Identifying Feelings) and describing emotions (Difficulty Describing Feelings) along with an externally oriented cognitive style (Externally-Oriented Thinking; Taylor et al., 1991).

About 10% of the general population manifests an elevated level of alexithymia (Mattila et al., 2006; Franz et al., 2008), which has been suggested to be a general vulnerability factor for various psychosomatic and mental disorders such as depression and anxiety (Rufer et al., 2004; Steinweg et al., 2011; Nowakowski et al., 2013). In fact, rates are higher in those diagnosed with Major Depressive Disorder (MDD; 23–46%; Honkalampi et al., 2000; Saarijärvi et al., 2001), and those who engage in self-harm behaviors (Gatta et al., 2016; Ludtke et al., 2016; Norman and Borrill, 2015).

One explanation for the link between alexithymia and self-harm behaviors may be the stress and tension associated with poor emotion processing skills (Bentley et al., 2014; Paivio and McCulloch, 2004; Spitzer et al., 2005). Individuals who have difficulty perceiving and understanding their own emotions may be particularly taxed by navigating emotionally

charged situations, especially when social exchanges require the interpretation of subtle or non-verbal emotional cues. Alexithymia, conceptualized as an impairment in conscious introspection about emotion, often co-occurs with poor emotion recognition in self and others (for review, see Grynberg et al., 2012), poor non-verbal expressiveness (Troisi et al., 1996), and impaired semantic representations of emotional concepts (Grynberg et al., 2012). However, it is also likely that alexithymia is related to atypical processing of emotional information that occurs through automatic sensory activation and physiological arousal and does not require conscious processes. For instance, emerging work suggests that alexithymia is linked to reduced spontaneous mimicry of facial expressions (Sonnby-Borgström, 2009), and impaired emotion labeling when the faces are presented rapidly or with visual degradation (Cook et al., 2013; Grynberg et al., 2012; Kätsyri et al., 2008; Parker et al., 2005; Prkachin et al., 2009; Swart et al., 2009). Together, these prior investigations suggest that alexithymia may be linked to both atypical conscious and automatic processing of emotion. Further, prior work reveals that individuals with elevated alexithymia are at more prone to acting impulsively under conditions of heightened negative affect (Fink et al., 2010; Shishido et al., 2013). It is possible that the stress and agitation resulting from poor emotion processing increases risk for impulsive behaviors including NSSI; however, the relationship between alexithymia and unconscious processing of emotion has not been assessed in the context of NSSI.

Converging brain imaging research has associated individual differences in alexithymia with the structure and function of the anterior cingulate cortex (ACC; Berthoz et al., 2002; Grabe et al., 2014; Kano et al., 2003; Koven et al., 2010; Lane et al., 1998), medial prefrontal cortex (Berthoz et al., 2002; Moriguchi et al., 2006; Ihme et al., 2014), the inferior and middle frontal cortex, orbitofrontal cortex, inferior parietal cortex, and occipital cortex in the right hemisphere (Ihme et al., 2014; Kano et al., 2003). Importantly, these regions, particularly the ACC, are engaged by emotional stimuli as well as during tasks requiring cognitive control (Shackman et al., 2011); as such, individual differences in the ability to detect and respond to emotional signals may be, in part, a function of the degree to which the ACC and connected regions activate while processing and responding to emotional cues (Lane et al., 1998). Crucially, the relationship between individual differences in alexithymia and automatic emotion processing can be explicitly examined using functional brain activity during tasks that assess emotion processing. For example, backward stimulus masking involves the very brief presentation of a stimulus (e.g., <40 ms) and immediate replacement with another visual stimulus for a longer duration. Under these conditions, participants typically are unaware of the initial “target” stimulus and only report perceiving the second “masking” stimulus (Esteves and Ohman, 1993; Morris et al., 1999). Previous studies using backward stimulus masking have shown activation in subcortical regions, including the amygdala, superior colliculus, and visual pulvinar, as well as in occipital and parietal cortices (e.g., Pine et al., 2001; Tamietto and de Gelder, 2010).

Research specifically relating alexithymia to deficits in automatic emotion processing and their neurobiological bases is only beginning to emerge (Donges and Suslow, 2017 for review). Alexithymia-focused studies have investigated adult brain reactivity to masked emotional facial expressions that are displayed for only a fraction of a second. Alexithymic individuals free of psychiatric diagnoses appear to encode affective information to a lesser

degree at an initial or automatic stage of processing, as alexithymia is related to diminished activation to masked emotional faces in the amygdala, insula, fusiform, parahippocampal gyrus, superior temporal gyrus, inferior frontal gyrus, and middle occipital gyrus (Eichmann et al., 2008; Duan et al., 2010; Kugel et al., 2008; Reker et al., 2010). In adults with MDD, high levels of alexithymia are related to decreased activation in right frontal regions and the right caudate nucleus in response to sad and happy (compared to neutral) masked faces when patients are instructed to evaluate the valence of the face, suggesting alexithymia has a modulating effect on automatic emotion processing in depression (Suslow et al., 2016). However, much work remains in the effort to understand the association between critical features of emotion processing in the context of NSSI and adolescence.

Given that aberrant emotion processing is often implicated in NSSI (Adrian et al., 2011; Crowell et al., 2009), a behavior associated with alexithymia, the present study assessed the relationship between alexithymia and automatic processing of emotional information in the brain. Specifically, our study examines neural reactivity to happy and fearful masked faces in adolescent females who self-injure. Further, we assess the role of alexithymia in automatic emotion processing within this group. Given prior research, we predict that alexithymia will be associated with diminished activation to masked emotional faces in the visual and frontal cortices. We will analyze associations between neural reactivity and alexithymia by using the subcomponents of alexithymia as predictors because they have been shown to have differential behavioral correlates (Larsen et al., 2003; Moriguchi et al., 2006; Demers and Koven, 2015). However, since there is limited research on distinct neural correlates of the subcomponents of alexithymia, we do not have specific hypotheses about the neural correlates of each.

2. Methods and materials

2.1. Participants

Participants included 25 females aged 13–22 years who exhibited NSSI behaviors. By including a large age range, we capture the timeframe in which NSSI is typically at its peak. As described in previous publications using this sample (Cullen et al., 2018; Schreiner et al., 2017), recruitment strategies included community postings and referrals from local mental health services. This study was part of a larger clinical trial ([ClinicalTrials.gov](https://clinicaltrials.gov) Identifier:). Due to the substantially higher rate of females who engage in NSSI behaviors and overrepresentation of females in the study, only females were included in analyses to create a more homogenous sample. All participants provided informed consent or assent, and parents of minors gave consent, in compliance with the University of Minnesota's Institutional Review Board. Participants were compensated for their time. Inclusion criteria included a history of engaging in NSSI at least 4 times, with at least 1 episode occurring in the last month. Exclusion criteria included a history of bipolar, pervasive developmental, or psychotic disorders, current pregnancy or breastfeeding, unstable medical illnesses, active suicidal intent, presence of magnetic resonance imaging (MRI) incompatible features, a positive urine drug screen, and intelligence quotient (IQ) of less than 80 as measured by the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). Demographic information can be found in Table 1.

All participants completed a comprehensive diagnostic assessment, conducted by trained clinicians or graduate students under the supervision of a licensed psychologist. Interviews were conducted separately with adolescents and parents for the Kiddie Schedule for Affective Disorders and Schizophrenia-Present and Lifetime Version (K-SADS-PL; Kaufman et al., 1997) for participants under 18 years, or with the adolescents who were over age 18 for the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID; First et al., 2002a, 2002b). NSSI was measured using the self-report Inventory of Statements About Self-Injury (ISAS; Glenn and Klonsky, 2011) and the clinician-administered Deliberate Self-Harm Inventory (DSHI; Gratz, 2001). Depression severity was measured with the Beck Depression Inventory-II (BDI; Beck et al., 1996).

2.2. Alexithymia

Alexithymia was measured using the TAS-20 (Taylor et al., 1991), a widely used self-report measure of alexithymia (Mantani et al., 2005). It is a 20-item scale that consists of three subscales or facets, including two affective facets, difficulty identifying feelings (DIF; e.g., “I am often confused about what emotion I am feeling;”) and difficulty describing feelings (DDF; e.g., “It is difficult for me to find the right words for my feelings;”), and one cognitive facet, externally oriented thinking (EOT; e.g., “I prefer talking to people about their daily activities rather than their feelings”; Taylor, et al., 1991; Zackheim, 2007). Higher scores indicate greater impairment. The TAS-20 has shown good test–retest reliability in non-patient samples across cultures (Kooiman et al., 2002; Taylor et al., 2003).

We also drew from the larger study’s set of other scales to assess constructs related to alexithymia. Due to the limitations previous research has found regarding the EOT subscale of the TAS-20 (e.g., Preece et al., 2017b) we sought other potential options for assessing this critical feature of alexithymia, including the Difficulties in Emotion Regulation Scale (DERS) Awareness subscale (6 items, e.g., “I pay attention to how I feel” [reverse-scored]; Gratz and Romer, 2004). Preece et al. (2017a) found that the TAS-20 EOT subscale and DERS Awareness subscale correlated highly, and in factor analysis, loaded on the same underlying “difficulty attending to feelings” factor. Importantly, the DERS has demonstrated good validity and reliability (Gratz and Roemer, 2004) and, therefore providing reliable information about EOT via the Awareness subscale. Data from this measure was missing from 3 participants due to addition of this measure after several participants had already been enrolled.

Data collected from an additional 5 individuals were excluded from the final sample due to scan data of insufficient quality (discontinued the scan early or had excessive head motion). Excluded individuals did not differ in terms of depression or alexithymia severity, frequency of NSSI, age, or IQ. One additional individual was not included in analyses because he was male, whereas all other participants were female. Six additional individuals only consented to the treatment portion of the parent study, and not the scanning session.

2.3. Behavioral fMRI paradigm

In the scanner, participants completed 5.2 minutes of a masked emotional faces task. Faces were presented in a block design format and contrasted with blocks of viewing a fixation

cross. Images were projected onto a screen at the back of the scanner and viewed through a mirror attached to the head coil. Stimuli consisted of standardized grayscale images of adult fearful, happy, and neutral expressions (Ekman and Friesen, 1976). Emotional faces were used as primes, and neutral faces of the same individuals were applied as masking stimuli. There were thirteen 24-s blocks (5 fixation (+), 4 happy (H), 4 fearful (F)) presented in a counterbalanced order: +FH+HF+HF+FH+. During face blocks, the emotional prime image was presented for 17 ms, followed a neutral mask of the same individual for 183 ms (total stimulus duration = 200 ms). Each pair of face stimuli was followed by 1300 ms of either a fixation cross or an “o”. Participants were instructed press a key with their pointer finger on a response pad held in their right hand whenever the letter “o” appeared on the screen, which appeared in 12.5% of trials. This was done to ensure that participants remained attentive throughout the task. During control blocks, face stimuli were replaced with a solid gray rectangle of the same size.

While facial expressions presenting numerous negative emotions have been shown to activate the amygdala (Fitzgerald et al., 2006), fearful stimuli were chosen based on research suggesting that amygdala response is more sensitive to viewing fearful faces than sad faces (Fusar-Poli et al., 2009). Similarly, happy faces were chosen as a comparison condition over neutral faces in order to maximize contrast in brain response given research suggesting that youth may show an exaggerated amygdala response to neutral faces over fearful faces (Thomas et al., 2001).

2.4. MRI acquisition

Data were acquired at the Center for Magnetic Resonance Research at the University of Minnesota using a Siemens 3T TIM Trio scanner and a 32-channel head coil. A five-minute structural scan was acquired using a T1-weighted high-resolution magnetization prepared gradient echo (MPRAGE) sequence: (echo time [TE] = 3.65 ms; repetition time [TR] = 2530 ms; inversion time [TI] = 1100 ms; flip angle = 7°; field of view [FOV] = 256 mm; matrix = 256 × 256; 1 mm isotropic voxel; 224 coronal slices). Task fMRI data were obtained using the WU-Minn Human Connectome Project consortium (<http://www.humanconnectome.org/>) multi-band EPI sequence: (TE = 30 ms; TR = 1320 ms; FOV = 212 mm; matrix = 106 × 106; 2 mm isotropic voxels; 64 oblique axial slices; multiband factor = 4). A ten-volume fMRI scan with matching scan parameters but reversed phase encoding direction was acquired prior to the task fMRI data for distortion correction.

2.5. fMRI data analysis

2.5.1. Preprocessing—MRI data were analyzed using FSL software (FMRIB Software Library, v. 5.0.2). Preprocessing began with motion correction of the fMRI data. Motion displacement was quantified using the root mean square of the resulting six motion correction parameter estimates. Volumes were assessed for censoring based on the following parameters: (1) absolute motion exceeding one voxel of overall displacement from the first volume in the series and (2) relative motion exceeding one half voxel from one volume to the next. Volumes immediately preceding and following those that met the relative criterion were also excluded. Participants were excluded if the number of volumes censored exceeded 25% of the scan. Additional preprocessing steps included brain extraction and distortion

correction of fMRI data using the reverse phase encoding scan and FSL's topup. EPI images were co-registered with each individual's anatomical image (using 6 df), normalized to Montreal Neurological Institute standard space (MNI, 152 T1 2-mm template, using 12 df), projected into MNI space, and spatially smoothed (FWHM 4 mm). High-pass temporal filtering was applied with a filter cutoff of 60 s based on task design.

2.5.2. Analyses—In first-level analyses, data from each individual subject were entered into a general linear model (GLM) using gamma-convolved predictors for masked fearful and masked happy blocks, with fixation as the unmarked baseline. Additional predictors of noninterest included six predictors for motion (three rotation and three linear translation), and predictors for censored volumes. Contrasts included masked fearful > masked happy, masked fearful > fixation, and masked happy > fixation.

Five group-level, whole-brain regression analyses were run for masked fearful > masked happy faces to test for associations between brain activity and facets of alexithymia (TAS-20 Total, DIF, DDF, EOT, and DERS Awareness). Separate models were used given the high degree of collinearity between the alexithymia facets. In each model, the alexithymia facet was de-meaned and served as a covariate of interest. Mean-centered age and IQ were included as nuisance variables. Significant regions of interaction (alexithymia by masked fearful > masked happy) were followed up using simple effects to determine whether the association with alexithymia was stronger for masked happy or for masked fearful faces. Unthresholded z-mean values were extracted for the masked fearful > fixation and masked happy > fixation contrasts within these same ROIs. Finally, we assessed correlations between these z-mean values for masked fearful > fixation and masked happy > fixation contrasts and each of the alexithymia facets using Pearson correlations. In all fMRI analyses, significance was assessed using FSL's cluster correction procedure with a voxelwise threshold of $p < .005$ and a cluster threshold of $p < .05$.

3. Results

3.1. Internal consistency and bivariate statistics

First, we examined the internal consistencies of the TAS-20 subscales and the DERS Emotion Awareness subscale. Internal consistency was $\alpha = 0.80$ for the DIF subscale, $\alpha = 0.59$ for the DDF subscale, and $\alpha = 0.24$ for the EOT subscale with the current sample. The sample internal consistency alpha for the DERS Awareness subscale was $\alpha = 0.94$. The DERS Awareness subscale has been previously equated to the EOT subscale of the TAS-20 (Preece et al., 2017a). We opted to focus on the DERS Awareness scale rather than the TAS-20 EOT given (a) the poor internal consistency of the EOT subscale in our data and other studies (e.g., Preece et al., 2017b; Kooiman et al., 2002; Loas et al., 2017) and (b) numerous psychometric investigations that have demonstrated that EOT has low levels of reliability, as evidenced by many of the EOT items not loading on their intended factor in factor analysis (e.g., Kooiman et al., 2002; Gignac et al., 2007; Preece et al., 2017b). Therefore, results based on the EOT subscale are included in the Supplement only.

Greater depression severity on the BDI-II was related to higher levels of alexithymia (r -values between 0.37 and 0.59 on the various subscales). Therefore, all models were also run with an additional nuisance variable for BDI-II score.

3.2. Activation to masked emotional faces

An analysis of differential reactivity to emotion (masked fearful > masked happy) in the whole sample revealed effects within regions spanning the bilateral lateral and fusiform occipital cortex, the bilateral supramarginal gyrus (SMG), the left inferior frontal gyrus, frontal orbital gyrus, and superior frontal gyrus, the left inferior temporal gyrus, and the bilateral temporal pole (voxelwise threshold of $p < .005$, uncorrected). However, these regions were small enough that they did not survive cluster correction (42–136 voxels). There were no regions that showed greater reactivity to masked happy compared to masked fearful.

3.3. Associations between alexithymia and activation to masked emotional faces

The TAS-20 total score did not relate to differential activation to fearful and happy masked faces. We also used separate analyses to examine the relationship between DIF, DDF, and EOT/Awareness dimensions of alexithymia and brain activity.

Using centered DIF score as a continuous predictor, we inspected whether there were any areas of the brain in which differential reactivity to masked fearful and happy faces related to an individual's difficulty identifying feelings. There were no regions that showed a relationship between DIF score and differential activity by emotion. Results did not change when the BDI-II score was used as an additional covariate.

We used the centered DDF score to examine whether there were any areas of the brain in which differential reactivity to masked fearful and happy faces related to an individual's difficulty defining feelings. There were no regions that showed a relationship between DDF score and differential activity by emotion. Results did not change when the BDI-II score was used as an additional covariate.

We used the centered DERS Awareness score (marker of EOT) to examine whether there were any areas of the brain in which differential activity to masked fearful and happy faces related to an individual's EOT. Three regions showed an interaction with emotion (masked fearful > happy) and DERS Awareness. These included clusters in the right SMG, left precentral gyrus, and right inferior frontal gyrus (Table 2; Fig. 1). When the BDI-II score was used as an additional covariate, only the right SMG showed an interaction with emotion (masked fearful > happy). Follow-up assessment of simple effects using z -mean values extracted from the significant ROIs showed that greater DERS Awareness was associated with decreased activation to masked happy faces (relative to fixation; Fig. 2) in the right inferior frontal gyrus, right SMG, and left precentral gyrus. DERS Awareness was positively related to activation to masked fear in the right SMG, but not related to activation to masked fear in the right inferior frontal gyrus or left precentral gyrus.

Results based on the centered TAS-20 EOT from the TAS-20 score are included in the Supplement.

4. Discussion

The present study assessed the relationship between alexithymia and brain measures of emotion processing in a sample of self-injuring adolescents. This study addressed automatic processing of emotional information that may occur outside of conscious awareness. We evaluated the separate effects of the alexithymia facets in the context of adolescent NSSI across diagnoses. Further, this study addressed whether hypothesized atypical automated processing of emotional faces in alexithymia is valence-specific or valence-general, by examining brain activity to masked happy and fearful faces separately.

Using a whole-brain approach, we found that one facet of alexithymia, elevated EOT (as measured by DERS Awareness), was related to differential activation to fearful and happy masked faces in multiple regions across the brain. This facet of alexithymia is considered the cognitive dimension, and reflects a utilitarian style of thinking that almost completely lacks inner an mental life of thoughts, attitudes and feelings. It is believed to direct thought to external reality rather than to feelings (Coffey et al., 2003) and correlates negatively with interoceptive awareness, as measured by accuracy in a heartbeat detection task (Herbert et al., 2011). On the other hand, the other facets of alexithymia were not related to differential activation to masked fear and happy faces in any brain regions. This finding echoes previous work on the differing functional and psychological correlates of the alexithymia facets and the need for separate analyses when examining alexithymia (Larsen et al., 2003; Moriguchi et al., 2006; Demers and Koven, 2015).

In particular, we found that a greater EOT, or decreased tendency to introspect, was related to decreased activation to masked happy faces relative to fixation. Self-injurers who reported not caring about or attending to their feelings showed attenuated neural activity to masked happy faces and heightened activity to masked fear faces in regions involved in visual attention and processing (Bush et al., 2000; Hampshire et al., 2010; Puce et al., 1996) and self-awareness (Cavanna and Trimble, 2006). EOT was related to differential activation to masked fearful and happy faces in a cluster that includes the right SMG, angular gyrus, and middle temporal gyrus. These regions are believed to play a role in recognition and understanding of emotions from human facial expressions (Adolphs et al., 2000), empathy (Silani et al., 2013), integration of multisensory information, autobiographical memory and social cognition (Seghier, 2013). Further, prior research has found links between alexithymia and these regions (van der Velde et al., 2013, 2014). Additionally, we observed that less activation in the left superior parietal lobule and right inferior frontal gyrus to masked happy faces was related to high EOT. Given previous work that suggests that the right inferior frontal gyrus responds to salient cues (Hampshire et al., 2010), it is possible that self-injurers with high EOT were less aware of the masked happy faces than those with lower EOT. This pattern of results may suggest that adolescents who self-harm and show higher EOT are less reactive to happy faces and more vigilant to fearful faces. Together, these results suggest that participants' visual detection of the masked faces may have differed by self-reported difficulty attending to emotions. Findings may implicate emotion processing anomalies at the initial, automatic stage for those with low emotion awareness in the context of NSSI.

A large body of work has supported the existence of biased attention to negative, or mood-congruent, information in depression (e.g., Peckham et al., 2010). While our work may be consistent with a negative attention bias in NSSI, the robust relationship between alexithymia and low neural reactivity to positive facial affect we observed has not been as extensively reported (e.g., Bylsma et al., 2008). However, given recent research on affect levels in individuals with NSSI, our results may fit in the mood-congruency framework. A latent class analysis identified high levels of negative affect and low levels of positive affect, along with dampening of positive affect in adolescents likely to engage in NSSI behaviors (Burke et al., 2018). Additionally, the attention-appraisal model of alexithymia (Preece et al., 2017a) that positions alexithymia within Gross' (2015) extended-process model of emotion regulation, explains the pattern of affect typical to those with high levels of alexithymia. The model posits that elevated negative reactivity in alexithymic individuals is due to both the reduced ability to up-regulate positive feelings and down-regulate negative feelings and moreover to difficulties evaluating emotion in order to activate regulatory attempts at all (Preece et al., 2017a). As such, our work may indicate that in the context of NSSI and elevated alexithymia (and particularly emotional awareness), automatic attention to emotional information is congruent with broader affect, in that it is both increased to negative stimuli and decreased to positive stimuli.

Previous work has found that self-reported low attention to emotion is related to behavioral measures of attention to emotional information, such as performance on an emotional Stroop task; however, valence-specific emotional attention has not been examined (Coffey et al., 2003). Coffey et al. examined emotional words in a Stroop paradigm using a single category, including positive- and negative-word trials. In the present study, we found that EOT's relationship with reactivity to masked faces differed by valence, suggesting that these individuals may devote fewer cognitive resources to evaluating positive emotional information at the automatic stage of processing. As such, future work assessing alexithymia's relationship with affective information processing should look at responses to positive and negative information separately. Further, in addition to studying negative biases in depression and NSSI, more work should focus on the diminished response to subtle positive cues, as this response style may support distinct treatment approaches.

The lack of a relationship between DIF and DDF and neural responding to masked faces is not congruent with previous reports. However, prior studies extracted voxel values from the fusiform gyrus and amygdala to perform analyses (Eichmann et al., 2008; Kugel et al., 2008), whereas we performed a whole-brain analysis with stringent thresholding.

4.1. Limitations

Despite important contributions to the extant literature, this study is not without limitations. First, the sample is relatively small, limiting the power to identify links between alexithymia and neural mechanisms. Also, the generalizability of our results is limited given the exclusion criteria of the study (e.g., bipolar, pervasive developmental, or psychotic disorders). However, we were particularly interested in the most common self-injury, which is that which occurs in the context of depression/anxiety during moments of negative affect. Psychosis and mania are less common conditions and the mechanisms of self-injury during

those episodes may differ from the majority of self-injurers. Additionally, generalizability may be limited because only females were included in the sample because most respondents to our study recruitment materials were females, which is consistent with higher rates of NSSI in females (Zetterqvist et al., 2013). Furthermore, our recruitment materials noted that treatment may be provided for those interested, so our results may apply primarily to treatment-seeking adolescents who engage in NSSI. Some consideration may be relevant to this sample that spanned a large age range, consistent with the developmental period when NSSI behaviors are most common. While developmental changes in emotion processing and self-regulatory abilities exist, these may be less relevant to the current analysis because developmental differences in top-down regulation are less likely to affect automatic processing. Additionally, nearly half the participants were using psychiatric medication, which may complicate the findings; however, additional analyses comparing those with versus without psychiatric medications revealed no differences in differential reactivity to fearful and happy masked faces.

Interval validity will need more attention in the future. We had significant skew and insufficient variability in our measures of NSSI severity and function, which prohibited us from examining how alexithymia and neural reactivity relate to these dimensional measures. Given that we did not have access to data from non-self-injuring adolescents matched on alexithymia severity, we only included adolescents who engaged in NSSI in our study. Therefore, future work is needed to determine if our findings would hold in non-self-injuring adolescents with high levels of alexithymia. It would also be prudent to measure current mood state of participants prior to completing the masked emotional faces task, in order to better understand the relationship between automatic attention to emotion and mood.

Critically, numerous psychometric investigations have demonstrated that the EOT subscale may have suboptimal reliability, and is consistently lower in childhood and adolescent samples (Kooiman et al., 2002; Loas et al., 2017; Preece et al., 2017b). Given the low internal consistency of the EOT subscale in our sample, and high internal consistency of the conceptually comparable DERS Awareness subscale, we focused on the measure from the DERS. While prior literature demonstrates substantial statistical overlap between these two subscales (e.g., Preece et al., 2017a; Brown et al., 2013), assessment of the items reveals that the DERS focuses on one's own emotions specifically, whereas the TAS-20 captures attention to emotions more broadly. It is noteworthy that the DERS Awareness score gives more focal localization of regions that differentially activate to masked fear and masked neutral faces than the EOT, with two of the three regions related to the DERS Awareness score within larger regions related to the EOT score (see Supplement). Still, additional research is needed to clarify the role of EOT in automatic processing of emotion in adolescents who self-injure, and should use a larger battery of self-report measures with subscales about externally-oriented cognitive styles that have higher reliability.

Finally, we chose to compare responses to fearful and happy masked faces with each other and use a fixation cross as baseline because some previous research has shown that children and adolescents may respond differently than adults to neutral images (Thomas et al., 2001). Due to this design, we are not able to directly determine reactivity to emotional faces compared to neutral faces.

4.2. Clinical implications

There are few available validated treatments available for adolescents who repeatedly engage in NSSI (Gonzales and Bergstrom, 2013; Muehlenkamp, 2006). Our findings suggest that in individuals with both NSSI and elevated levels of alexithymia it may be effective to focus on augmenting attention to positive emotions, as a small study has found for adults with anxiety and depressive disorders (Carl et al., 2017). Further, our findings lend a neurobiologically-based explanation for the success of NSSI treatments that focus on the use of mindfulness, such as Dialectical Behavior Therapy. Self-harm is often engaged in the context of emotional distress related to social situations (Bentley et al., 2014). Adolescents with NSSI have difficulty evaluating interpersonal situations (Tatnell et al., 2017); our work is consistent with the idea that such difficulty relates to reduced vigilance to positive social information. Mindfulness techniques that guide patients to focus on the most pertinent features of an emotional response and to understand and mentally represent emotional responses and related bodily sensations (e.g., Harris, 2009; Kennedy and Franklin, 2002) could be used to target these deficits in automatic processing of positive emotions. Furthermore, the attention-appraisal model of alexithymia (Preece et al., 2017a) that fits our data supports development of emotion schemas in psychiatric patients with high levels of alexithymia to help them reduce use of experiential avoidance, which may include forms of NSSI, as an emotion regulation strategy (Preece et al., 2017a). The present study highlights the role of attention to positive and negative emotion at early stages of emotional processing in adolescents who self-harm. As such, our work may indicate that in the context of NSSI and elevated EOT, automatic attention to emotional information is congruent with a person's general affect in that it is both increased to negative stimuli and decreased to positive stimuli.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors would like to sincerely thank the participants and families that participated in this study. The study was funded by National Institute of Mental Health grant 1R21MH094558 (Dr. Cullen) and the University of Minnesota Academic Health Center Faculty Research Development Grant Program (Grant #. 11.12). The authors acknowledge the Minnesota Supercomputing Institute (MSI) at the University of Minnesota for providing resources that contributed to the research results reported within this paper. URL: <http://www.msi.umn.edu>. Trainee support was provided by the University of Minnesota's Institute of Child Development via a National Institute of Mental Health National Research Service Award Grant no. 2T32MH015755-39 (to LAD).

References

- Adrian M, Zeman J, Erdley C, Lisa L, Sim L, 2011 Emotional dysregulation and interpersonal difficulties as risk factors for nonsuicidal self-injury in adolescent girls. *J. Abnorm. Child Psychol.* 39 (3), 389–400. [PubMed: 20953828]
- Adolphs R, Damasio H, Tranel D, Cooper G, Damasio AR, 2000 A role for somatosensory cortices in the visual recognition of emotion as revealed by three-dimensional lesion mapping. *J. Neurosci* 20 (7), 2683–2690. [PubMed: 10729349]
- American Psychiatric Association, 2013 Diagnostic and Statistical Manual of Mental disorders: DSM-5 American Psychiatric Association, Washington, DC.

- Beck AT, Steer RA, Brown GK, 1996 Manual for the Beck Depression Inventory-II Psychological Corporation, San Antonio, TX.
- Bentley KH, Nock MK, Barlow DH, 2014 The four-function model of nonsuicidal self-injury: key directions for future research. *Clin. Psychol. Sci* 2 (5), 638–656.
- Berthoz S, Artiges E, Van de Moortele PF, Poline JB, Rouquette S, Consoli SM, Martinot JL, 2002 Effect of impaired recognition and expression of emotions on frontocingulate cortices: an fMRI study of men with alexithymia. *Am. J. Psychiatry* 159, 961–967. [PubMed: 12042184]
- Black EB, Mildred H, 2016 Characteristics of non-suicidal self-injury in women accessing internet help sites. *Clin. Psychol* 22, 37–45.
- Brown RJ, Bouska JF, Frow A, Kirkby A, Baker GA, Kemp S, et al., 2013 Emotional dysregulation, alexithymia, and attachment in psychogenic nonepileptic seizures. *Epilepsy Behav* 29 (1), 178–183. [PubMed: 23973643]
- Burke TA, McArthur BA, Daryanani I, Abramson LY, Alloy LB, 2018 Latent classes of trait affect and cognitive affective regulation strategies are associated with depression, non-suicidal self-injury, and well-being. *J. Affect. Disord* 225, 180–187. [PubMed: 28837951]
- Bush G, Luu P, Posner MI, 2000 Cognitive and emotional influences in anterior cingulate cortex. *Trends Cogn. Sci* 4 (6), 215–222. [PubMed: 10827444]
- Bylsma LM, Morris BH, Rottenberg J, 2008 A meta-analysis of emotional reactivity in major depressive disorder. *Clin. Psychol. Rev* 28 (4), 676–691. [PubMed: 18006196]
- Carl JR, Gallagher MW, Barlow DH, 2017 Development and preliminary evaluation of a positive emotion regulation augmentation module for anxiety and depression. *Behav. Therapy* 49, 939–950.
- Cavanna AE, Trimble MR, 2006 The precuneus: a review of its functional anatomy and behavioural correlates. *Brain* 129 (3), 564–583. [PubMed: 16399806]
- Coffey E, Berenbaum H, Kerns J, 2003 The dimensions of emotional intelligence, alexithymia, and mood awareness: associations with personality and performance on an emotional stroop task. *Cognit. Emot* 17 (4), 671–679. [PubMed: 29715729]
- Cook R, Brewer R, Shah P, Bird G, 2013 Alexithymia, not autism, predicts poor recognition of emotional facial expressions. *Psychol. Sci* 24 (5), 723–732. [PubMed: 23528789]
- Crowell SE, Beauchaine TP, Linehan MM, 2009 A biosocial developmental model of borderline personality: elaborating and extending Linehan's theory. *Psychol. Bull* 135 (3), 495–510. [PubMed: 19379027]
- Cullen KR, Klimes-Dougan B, Westlund Schreiner M, Carstedt P, Marka N, Nelson K, Miller MJ, Reigstad K, Westervelt A, Gunlicks-Stoessel M, Eberly LE, 2018 N-acetylcysteine for nonsuicidal self-injurious behavior in adolescents: an open-label pilot study. *J. Child Adolesc. Psychopharmacol* 28 (2), 136–144. [PubMed: 29053023]
- Demers LA, Koven NS, 2015 The relation of alexithymic traits to affective theory of mind. *Am. J. Psychol* 128 (1), 31–42. [PubMed: 26219172]
- Donges U-S, Suslow T, 2017 Alexithymia and automatic processing of emotional stimuli: a systematic review. *Rev. Neurosci* 28 (3), 247–264. [PubMed: 28099136]
- Duan X, Dai Q, Gong Q, Chen H, 2010 Neural mechanism of unconscious perception of surprised facial expression. *NeuroImage* 52 (1), 401–407. 10.1016/j.neuroimage.2010.04.021. [PubMed: 20398771]
- Eichmann M, Kugel H, Suslow T, 2008 Difficulty identifying feelings and automatic activation in the fusiform gyrus in response to facial emotion. *Percept. Motor Skill* 107 (3), 915–922.
- Ekman P, Friesen WV, 1976 Measuring facial movement. *Environ. Psychol. Nonverbal Behav* 1 (1), 56–75.
- Esteves F, Öhman A, 1993 Masking the face: recognition of emotional facial expressions as a function of the parameters of backward masking. *Scand. J. Psychol* 34 (1), 1–18. [PubMed: 8322040]
- Fink EL, Anestis MD, Selby EA, Joiner TE, 2010 Negative urgency fully mediates the relationship between alexithymia and dysregulated behaviours. *Personal. Mental Health* 293 (, 4), 284–293.
- First MB, Spitzer RL, Gibbon M, Williams JBW, 2002a Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Research Version, Patient Edition. (SCID-I/P)

- First MB, Spitzer RL, Gibbon M, Williams JBW, 2002b Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Research Version, Non-patient Edition. (SCID-I/NP)
- Fitzgerald DA, Angstadt M, Jelsone LM, Nathan PJ, Phan KL, 2006 Beyond threat: amygdala reactivity across multiple expressions of facial affect. *Neuroimage* 30 (4), 1441–1448. [PubMed: 16368249]
- Fliege H, Lee JR, Grimm A, Klapp BF, 2009 Risk factors and correlates of deliberate self-harm behavior: a systematic review. *J. Psychosom. Res* 66 (6), 477–493. [PubMed: 19446707]
- Franz M, Popp K, Schaefer R, Sitte W, Schneider C, Hardt J, et al., 2008 Alexithymia in the German general population. *Soc. Psychiatry Psychiatr. Epidemiol* 43 (1), 54–62. [PubMed: 17934682]
- Fusar-Poli P, Placentino A, Carletti F, Landi P, Allen P, Surguladze S, et al., 2009 Functional atlas of emotional faces processing: a voxel-based meta-analysis of 105 functional magnetic resonance imaging studies. *J. Psychiatry Neurosci* 34 (6), 418–432. [PubMed: 19949718]
- Gatta M, Dal Santo F, Rago A, Spoto A, Battistella PA, 2016 Alexithymia, impulsiveness, and psychopathology in nonsuicidal self-injured adolescents. *Neuropsych. Dis. Treat* 12, 2307.
- Gignac GE, Palmer BR, Stough C, 2007 A confirmatory factor analytic investigation of the TAS-20: corroboration of a five-factor model and suggestions for improvement. *J. Personal. Assess* 89 (3), 247–257.
- Glenn CR, Klonsky ED, 2013 Nonsuicidal self-injury disorder: an empirical investigation in adolescent psychiatric patients. *J. Clin. Child Adolesc* 42 (4), 496–507.
- Glenn CR, Klonsky ED, 2011 One-year test-retest reliability of the Inventory of Statements about Self-Injury (ISAS). *Assessment* 18, 375–378. 10.1177/1073191111411669. [PubMed: 21665881]
- Gonzales AH, Bergstrom L, 2013 Adolescent non-suicidal self-injury (NSSI) interventions. *J. Child Adolesc. Psychiatr. Nurs* 26 (2), 124–130. [PubMed: 23607824]
- Grabe HJ, Wittfeld K, Hegenscheid K, Hosten N, Lotze M, Janowitz D, et al., 2014 Alexithymia and brain gray matter volumes in a general population sample. *Hum. Brain Mapp* 35 (12), 5932–5945. [PubMed: 25081815]
- Gratz KL, 2001 Measurement of deliberate self-harm: preliminary data on the deliberate self-harm inventory. *J. Psychopathol. Behav. Assess* 23, 253–263.
- Gratz KL, Roemer L, 2004 Multidimensional assessment of emotion regulation and dysregulation: development, factor structure, and initial validation of the difficulties in emotion regulation scale. *J. Psychopathol. Behav. Assess* 26, 41–54.
- Gross JJ, 2015 Emotion regulation: current status and future prospects. *Psychol. Inq* 26, 1–26.
- Grynberg D, Chang B, Corneille O, Maurage P, Vermeulen N, Berthoz S, Luminet O, 2012 Alexithymia and the processing of emotional facial expressions (EFEs): systematic review, unanswered questions and further perspectives. *PLoS ONE* 7 (8), e42429. [PubMed: 22927931]
- Hampshire A, Chamberlain SR, Monti MM, Duncan J, Owen AM, 2010 The role of the right inferior frontal gyrus: inhibition and attentional control. *Neuroimage* 50, 1313–1319. [PubMed: 20056157]
- Harris R, 2009 ACT Made simple: An Easy-To-Read Primer on Acceptance and Commitment Therapy New Harbinger Publications.
- Herbert BM, Herbert C, Pollatos O, 2011 On the relationship between interoceptive awareness and alexithymia: is interoceptive awareness related to emotional awareness? *J. Personal* 79 (5), 1149–1175.
- Honkalampi K, Hintikka J, Tanskanen A, Lehtonen J, Viinamäki H, 2000 Depression is strongly associated with alexithymia in the general population. *J. Psychosom. Res* 48 (1), 99–104. [PubMed: 10750635]
- Ihme K, Sacher J, Lichev V, Rosenberg N, Kugel H, Rufer M, et al., 2014 Alexithymic features and the labeling of brief emotional facial expressions—an fMRI study. *Neuropsychologia* 64, 289–299. [PubMed: 25281889]
- In-Albon T, Ruf C, Schmid M, 2013 Proposed diagnostic criteria for the DSM-5 of nonsuicidal self-injury in female adolescents: diagnostic and clinical correlates. *Psychiatry J* 2013, 1–12.
- Jacobson CM, Gould M, 2007 The epidemiology and phenomenology of non-suicidal self-injurious behavior among adolescents: a critical review of the literature. *Arch. Suicide Res* 11, 129–147. [PubMed: 17453692]

- Kano M, Fukudo S, Gyoba J, Kamachi M, Tagawa M, Mochizuki H, et al., 2003 Specific brain processing of facial expressions in people with alexithymia: an H215O-PET study. *Brain* 126 (6), 1474–1484. [PubMed: 12764066]
- Kätsyri J, Saalasti S, Tiippana K, von Wendt L, Sams M, 2008 Impaired recognition of facial emotions from low-spatial frequencies in Asperger syndrome. *Neuropsychologia* 46 (, 7), 1888–1897. [PubMed: 18314147]
- Kaufman J, Birmaher B, Brent D, Rao U, Flynn C, Moreci P, Williamson D, Ryan N, 1997 Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL): initial reliability and validity data. *J. Am. Acad. Child Adolesc. Psychiatry* 36, 980–988. [PubMed: 9204677]
- Kennedy M, Franklin J, 2002 Skills-based treatment for alexithymia: an exploratory case series. *Behav. Change* 19 (3), 158–171.
- Klonsky ED, May AM, Glenn CR, 2013 The relationship between nonsuicidal selfinjury and attempted suicide: converging evidence from four samples. *J. Abnorm. Psychol* 122 (1), 231. [PubMed: 23067259]
- Kooiman CG, Spinhoven P, Trijsburg RW, 2002 The assessment of alexithymia: a critical review of the literature and a psychometric study of the Toronto Alexithymia Scale-20. *J. Psychosom. Res* 53 (6), 1083–1090. 10.1016/S0022-3999(02)00348-3. [PubMed: 12479990]
- Koven NS, Roth RM, Garlinghouse MA, Flashman LA, Saykin AJ, 2010 Regional gray matter correlates of perceived emotional intelligence. *Soc. Cogn. Affect. Neurosci* 6 (5), 582–590. [PubMed: 20934987]
- Kugel H, Eichmann M, Dannlowski U, Ohrmann P, Bauer J, Arolt V, et al., 2008 Alexithymic features and automatic amygdala reactivity to facial emotion. *Neurosci. Lett* 435 (1), 40–44. 10.1016/j.neulet.2008.02.005. [PubMed: 18314269]
- Lane RD, Reiman EM, Axelrod B, Yun LS, Holmes A, Schwartz GE, 1998 Neural correlates of levels of emotional awareness: evidence of an interaction between emotion and attention in the anterior cingulate cortex. *J. Cogn. Neurosci* 10 (4), 525–535. [PubMed: 9712681]
- Larsen JK, Brand N, Bermond B, Hijman R, 2003 Cognitive and emotional characteristics of alexithymia: a review of neurobiological studies. *J. Psychosom. Res* 54 (6), 533–541. [PubMed: 12781307]
- Loas G, Braun S, Delhay M, Linkowski P, 2017 The measurement of alexithymia in children and adolescents: psychometric properties of the Alexithymia Questionnaire for Children and the twenty-item Toronto Alexithymia Scale in different non-clinical and clinical samples of children and adolescents. *PLoS ONE* 12 (5), e0177982. [PubMed: 28542508]
- Lloyd-Richardson EE, Perrine N, Dierker L, Kelley ML, 2007 Characteristics and functions of non-suicidal self-injury in a community sample of adolescents. *Psychol. Med* 37 (8), 1183–1192. [PubMed: 17349105]
- Lüdtke J, In-Albon T, Michel C, Schmid M, 2016 Predictors for DSM-5 nonsuicidal self-injury in female adolescent inpatients: the role of childhood maltreatment, alexithymia, and dissociation. *Psychiatry Res* 239, 346–352. 10.1016/j.psychres.2016.02.026. [PubMed: 27088878]
- Mantani T, Okamoto Y, Shirao N, Okada G, Yamawaki S, 2005. Reduced activation of posterior cingulate cortex during imagery in subjects with high degrees of alexithymia: A functional magnetic resonance imaging study. *Biol. Psychiatry* 57 (9), 982–990. 10.1016/j.biopsych.2005.01.047. [PubMed: 15860338]
- Mattila AK, Salminen JK, Nummi T, Joukamaa M, 2006 Age is strongly associated with alexithymia in the general population. *J. Psychosom. Res* 61 (5), 629–635. [PubMed: 17084140]
- Moriguchi Y, Decety J, Ohnishi T, Maeda M, Mori T, Nemoto K, et al., 2006 Empathy and judging other's pain: an fMRI study of alexithymia. *Cerebral Cortex* 17 (9), 2223–2234. [PubMed: 17150987]
- Morris JS, Öhman A, Dolan RJ, 1999 A subcortical pathway to the right amygdala mediating “unseen” fear. *Proc. Natl. Acad. Sci* 96 (4), 1680–1685. [PubMed: 9990084]
- Muehlenkamp JJ, 2006 Empirically supported treatments and general therapy guidelines for non-suicidal self-injury. *J. Mental Health Couns* 28 (2), 166–185.

- Nock MK, 2009 Why do people hurt themselves? New insights into the nature and functions of self-injury. *Curr. Dir. Psychol. Sci* 18, 78–83. [PubMed: 20161092]
- Norman H, Borrill J, 2015 The relationship between self-harm and alexithymia. *Scand. J. Psychol* 56 (4), 405–419. [PubMed: 26011069]
- Nowakowski ME, McFarlane T, Cassin S, 2013 Alexithymia and eating disorders: a critical review of the literature. *J. Eat. Disord* 1 (1), 21. [PubMed: 24999402]
- Paivio SC, McCulloch CR, 2004 Alexithymia as a mediator between childhood trauma and self-injurious behaviors. *Child Abuse Neglect* 28 (3), 339–354. [PubMed: 15066350]
- Parker PD, Prkachin KM, Prkachin GC, 2005 Processing of facial expressions of negative emotion in alexithymia: the influence of temporal constraint. *J. Personal* 73 (4), 1087–1107.
- Peckham AD, McHugh RK, Otto MW, 2010 A meta-analysis of the magnitude of biased attention in depression. *Depress. Anxiety* 27 (12), 1135–1142. [PubMed: 21049527]
- Pine DS, Grun J, Zarahn E, Fyer A, Koda V, Li W, et al., 2001 Cortical brain regions engaged by masked emotional faces in adolescents and adults: an fMRI study. *Emotion* 1 (2), 137. [PubMed: 12899193]
- Preece D, Becerra R, Allan A, Robinson K, Dandy J, 2017a Establishing the theoretical components of alexithymia via factor analysis: introduction and validation of the attention-appraisal model of alexithymia. *Personal. Individ. Differ* 119, 341–352. 10.1016/j.paid.2017.08.003.
- Preece D, Becerra R, Robinson K, Dandy J, 2017b Assessing alexithymia: psychometric properties and factorial invariance of the 20-Item Toronto alexithymia scale in nonclinical and psychiatric samples. *J. Psychopathol. Behav. Assess* 40, 1–12.
- Prkachin GC, Casey C, Prkachin KM, 2009 Alexithymia and perception of facial expressions of emotion. *Personal. Individ. Differ* 46 (4), 412–417.
- Puce A, Allison T, Asgari M, Gore JC, McCarthy G, 1996 Differential sensitivity of human visual cortex to faces, letterstrings, and textures: a functional magnetic resonance imaging study. *J. Neurosci* 16 (16), 5205–5215. [PubMed: 8756449]
- Reker M, Ohrmann P, Rauch AV, Kugel H, Bauer J, Dannlowski U, ..., Suslow T, 2010 Individual differences in alexithymia and brain response to masked emotion faces. *Cortex* 46 (5), 658–667. 10.1016/j.cortex.2009.05.008. [PubMed: 19524887]
- Rufer M, Hand I, Braatz A, Alsleben H, Fricke S, Peter H, 2004 A prospective study of alexithymia in obsessive-compulsive patients treated with multimodal cognitive-behavioral therapy. *Psychother. Psychosom* 73, 101–106. [PubMed: 14767152]
- Saarijärvi S, Salminen JK, Toikka TB, 2001 Alexithymia and depression: a 1-year follow-up study in outpatients with major depression. *J. Psychosom. Res* 51 (6), 729–733. [PubMed: 11750295]
- Schreiner MW, Klimes-Dougan B, Mueller BA, Eberly LE, Reigstad KM, Carstedt PA, et al., 2017 Multi-modal neuroimaging of adolescents with non-suicidal self-injury: Amygdala functional connectivity. *J. Affect. Disord* 221, 47–55. [PubMed: 28628767]
- Seghier ML, 2013 The angular gyrus: multiple functions and multiple subdivisions. *Neuroscientist* 19 (1), 43–61. [PubMed: 22547530]
- Shackman AJ, Salomons TV, Slagter HA, Fox AS, Winter JJ, Davidson RJ, 2011 The integration of negative affect, pain and cognitive control in the cingulate cortex. *Nat. Rev. Neurosci* 12 (3), 154. [PubMed: 21331082]
- Shishido H, Gaher RM, Simons JS, 2013 I don't know how I feel, therefore I act: alexithymia, urgency, and alcohol problems. *Addict. Behav* 38 (4), 2014–2017. [PubMed: 23384454]
- Sifneos PE, 1973 The prevalence of 'alexithymic' characteristics in psychosomatic patients. *Psychother. Psychosom* 22, 255–262.
- Silani G, Lamm C, Ruff CC, Singer T, 2013 Right supramarginal gyrus is crucial to overcome emotional egocentricity bias in social judgments. *J. Neurosci* 33 (39), 15466–15476. [PubMed: 24068815]
- Sonnby-Borgström M, 2009 Alexithymia as related to facial imitation, mentalization, empathy, and internal working models-of-self and-others. *Neuropsychoanalysis* 11 (1), 111–128.
- Spitzer C, Siebel-Jürges U, Barnow S, Grabe HJ, Freyberger HJ, 2005 Alexithymia and interpersonal problems. *Psychother. Psychosom* 74 (4), 240–246. [PubMed: 15947514]

- Steinweg DL, Dallas AP, Rea WS, 2011 Fibromyalgia: unspeakable suffering, a prevalence study of alexithymia. *Psychosomatics* 52, 255–262. [PubMed: 21565597]
- Suslow T, Kugel H, Rufer M, Redlich R, Dohm K, Grotegerd D, et al., 2016 Alexithymia is associated with attenuated automatic brain response to facial emotion in clinical depression. *Prog. Neuro-Psychopharmacol* 65, 194–200. 10.1016/j.pnpbp.2015.10.006.
- Swart M, Kortekaas R, Aleman A, 2009 Dealing with feelings: characterization of trait alexithymia on emotion regulation strategies and cognitive-emotional processing. *PLoS ONE* 4 (6), e5751. [PubMed: 19492045]
- Tamietto M, De Gelder B, 2010 Neural bases of the non-conscious perception of emotional signals. *Nat. Rev. Neurosci* 11 (10), 697. [PubMed: 20811475]
- Tatnell R, Hasking P, Lipp OV, Boyes M, Dawkins J, 2017 Emotional responding in NSSI: examinations of appraisals of positive and negative emotional stimuli, with and without acute stress. *Cognit. Emot* 32, 1–13.
- Taylor GJ, Bagby RM, Parker JD, 1991 The alexithymia construct: a potential paradigm for psychosomatic medicine. *Psychosomatics* 32 (2), 153–164. [PubMed: 2027937]
- Taylor G, Bagby R, Parker J, 2003 The 20-item Toronto Alexithymia Scale: IV. Reliability and factorial validity in different languages and cultures. *J. Psychosom. Res* 55, 277–283. [PubMed: 12932803]
- Thomas KM, Drevets WC, Whalen PJ, Eccard CH, Dahl RE, Ryan ND, Casey BJ, 2001 Amygdala response to facial expressions in children and adults. *Biol. Psychiatry* 49 (4), 309–316. [PubMed: 11239901]
- Troisi A, Delle Chiaie R, Russo F, Russo MA, Mosco C, Pasini A, 1996 Nonverbal behavior and alexithymic traits in normal subjects: individual differences in encoding emotions. *J. Nerv. Ment. Dis* 189, 31–316.
- Tuisku V, Kiviruusu O, Pelkonen M, Karlsson L, Strandholm T, Marttunen M, 2014 Depressed adolescents as young adults—predictors of suicide attempt and non-suicidal self-injury during an 8-year follow-up. *J. Affect. Disord* 152, 313–319. [PubMed: 24144580]
- Van der Velde J, Servaas MN, Goerlich KS, Bruggeman R, Horton P, Costafreda SG, Aleman A, 2013 Neural correlates of alexithymia: a meta-analysis of emotion processing studies. *Neurosci. Biobehav. Rev* 37 (8), 1774–1785. [PubMed: 23886515]
- van der Velde J, van Tol MJ, Goerlich-Dobre KS, Gromann PM, Swart M, de Haan L, Wiersma D, Bruggeman R, Krabbendam L, Aleman A, 2014 Dissociable morphometric profiles of the affective and cognitive dimensions of alexithymia. *Cortex* 54, 190–199. [PubMed: 24699037]
- Wechsler D, 1999 Wechsler Abbreviated Scale of Intelligence The Psychological Corporation: Harcourt Brace & Company, New York, NY.
- Zackheim L, 2007 Alexithymia: the expanding realm of research. *J. Psychosom. Res* 63 (4), 345–347. 10.1016/j.jpsychores.2007.08.011. [PubMed: 17905040]
- Zetterqvist M, Lundh LG, Dahlström Ö, Svedin CG, 2013 Prevalence and function of non-suicidal self-injury (NSSI) in a community sample of adolescents, using suggested DSM-5 criteria for a potential NSSI disorder. *J. Abnorm. Child Psychol* 41 (5), 759–773. [PubMed: 23344701]

Fig. 1.
Regions in which differential activation to masked happy and fearful faces correlated with EOT (measured by DERS Awareness subscale), $p < .05$ cluster corrected.

Fig. 2.

Relationship between EOT and brain activation for fearful or happy faces. EOT was measured by centered DERS Awareness score. Brain activation reflects extracted z -mean values for fearful vs. fixation and happy vs. fixation contrasts. Means were extracted from ROIs showing correlations between DERS Awareness and fearful > happy masked faces. Dark and light dashed lines represent linear fit to the fear vs. fixation and happy vs. fixation data, respectively.

Table 1

Demographics and sample characteristics.

Sample Characteristics	N = 25
Age, <i>M</i> (<i>SD</i>)	17.30 (2.35)
Race, <i>n</i> (%)	
White	24 (96%)
African American	1 (4%)
Asian	0 (0%)
Native American	0 (0%)
WASI-II IQ, <i>M</i> (<i>SD</i>)	<i>n</i> =24, 104.7 (10.71)
BDI-II, <i>M</i> (<i>SD</i>)	27.72 (12.50)
TAS-20, <i>M</i> (<i>SD</i>)	59.60 (10.31)
DIF, <i>M</i> (<i>SD</i>)	20.64 (5.72)
DDF, <i>M</i> (<i>SD</i>)	17.80 (3.73)
EOT, <i>M</i> (<i>SD</i>)	21.16 (3.72)
DERS awareness, <i>M</i> (<i>SD</i>)	21.41 (6.35)
DSM-IV diagnoses, <i>n</i> (%)	
Mood disorder	Current: 17 (68%) Ever: 21 (84%)
Anxiety disorder	Current: 11 (44%) Ever: 12 (48%)
Alcohol use disorder	Current: 1 (4%) Current: 1 (4%)
Eating disorder	Current: 1 (4%) Ever: 3 (12.5%)
PTSD	Current: 1 (4%) Ever: 1 (4%)
Total # of diagnoses, range, <i>M</i> (<i>SD</i>)	0 – 4, 1.36 (1.08)
ISAS, number of episodes (Lifetime)	range, <i>M</i> (<i>SD</i>)
Cutting	5–730, 131.84 (206.39)
Interfere with wound	0–500, 106.30 (173.06)
Severe scratching	0–500, 47.04 (143.09)
Rubbing skin	0–500, 37.67 (127.85)
Hair pulling	0–648, 29.83 (132.09)
Banging/hitting self	0–400, 27.52 (81.42)
Burning	0–100, 15.80 (27.26)
Pinching	0–200, 12.98 (41.31)
Sticking with needles	0–100, 7.64, (20.38)
Biting	0–100, 7.54 (21.12)
Carving	0–20, 2.16 (4.80)
Swallowing substances	0–15, 0.63 (3.06)

Table 2

Alexithymia effects on differential activation to masked fearful and happy faces.

Region	Side	Volume (mm ³)	z-max	MINI Coordinates			z	z mean	z standard deviation
<i>Regions showing differential activation by DERS Awareness</i>									
Supramarginal gyrus	R	6024	3.77	64	-44		26	2.88	0.26
Precentral gyrus	L	1816	3.52	-16	-34		64	2.87	0.22
Inferior frontal gyrus	R	1504	3.47	46	12		24	2.85	0.20

All analyses included age and IQ as demeaned covariates.