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Emotional working memory updating in individuals with borderline personality features

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Abstract

Background and Objectives. Individuals with features of borderline personality disorder (BPD) are highly sensitive to social rejection. Working memory (WM) may play a critical role in processing emotional interpersonal information in BPD. Yet, little is known about how emotional WM operations are related to sensitivity to rejection cues and BPD features. Therefore, this study examined relationships among emotional WM operations, rejection sensitivity, and BPD features.

Methods. Participants with BPD features (n=39 with non-suicidal self-injury history; n=47 without non-suicidal self-injury history) and healthy participants (n=46) completed an emotional two-back task before and after a social exclusion induction (the Cyberball game). Results. Results showed that participants with BPD features were slower at discarding faces expressing anger and pain from WM compared to healthy individuals before the social exclusion induction. Participants with BPD features and a history of self-injury were also slower at entering happy faces into WM compared to the other participants. Moreover, across participants, slower WM discarding of angry and pain faces was associated with higher levels of rejection sensitivity. Finally, no group differences emerged with respect to WM entering and discarding operations for emotional faces in response to social exclusion.

Limitations. This study was conducted in a sample of undergraduate students and did not consider comorbidity with other forms of psychopathology.

Conclusions. These findings cast light on how emotional WM difficulties may be involved in how individuals with BPD process emotional interpersonal information.

Keywords: working memory; updating; borderline personality; self-injury; emotional information-processing.

1. Introduction

Borderline personality disorder (BPD) is a severe mental disorder characterized by pervasive instability in affect and interpersonal relationships (American Psychiatric Association, 2013). Heightened interpersonal sensitivity is a prominent feature of the disorder (Gunderson, & Lyons-Ruth, 2008). Individuals with BPD are hypersensitive to interpersonal threats (Barnett, Veague & Hooley, 2014; Skodol et al., 2002), preoccupied with evaluations of others, vigilant to the behavior of others, and experience fear social rejection (Boyce & Parker, 1989; Slanbekova et al., 2018). When being exposed to rejection or invalidating situations (e.g., social exclusion), individuals with BPD experience intense negative emotions, increased ruminative and catastrophic thoughts (Selby & Joiner, 2009), and display non-suicidal self-injury more frequently (NSSI; Snir et al., 2015; Turner et al., 2016). Interpersonal hypersensitivity can trigger anger (Barnow et al., 2009), feelings of social rejection, and aggressive or self-destructive behaviors (Bertsch et al., 2017; Manke, Herpertz, & Bertsch, 2015; Sansone & Sansone, 2012). Identifying the mechanisms underlying heightened interpersonal sensitivity may enable a deeper understanding of the hallmark features of this detrimental disorder.

An emerging line of research is aimed at uncovering how individuals with BPD process emotional interpersonal information (e.g., Hill et al., 2008). This research typically focused on the role of attention, interpretation, and memory processes (Baer et al., 2012; Beblo et al., 2011; Bertsch et al., 2017; Dyke et al., 2009; Fertuck et al., 2006; Kaiser et al., 2016; Mitchell et al., 2014; Ruocco, 2005). To date, however, fewer studies have examined the role of working memory (WM) difficulties in response to emotionally distressing contexts (e.g., social exclusion) or when processing emotional information. WM refers to a temporary and limited-capacity store that operates at the intersection between external (e.g., cues in the environment) and internal (e.g., memory representations) sources of information (Chun et al., 2011).

Therefore, studying WM may be particularly important to understand how individuals with BPD process emotional and interpersonal information.

Some studies have examined the role of general WM difficulties in individuals with BPD. Current findings suggest that WM performance may be impaired in individuals with BPD. For example, studies have shown that individuals with BPD are less accurate on WM tasks such as n-back tasks (Black et al., 2009; Hagenhoff et al., 2013; Lazzaretti et al., 2012) and delayed matching to sample tasks (Stevens et al., 2004). One study investigated the impact of emotional distress on working memory performance (Bellovin-Weiss, 2014). Groups of individuals with BPD, major depressive disorder (MDD), and healthy controls were compared with respect to their WM performance in response to a social stress task. Results showed that there were no baseline differences in WM functions across the three groups. However, after controlling for the effects of emotional distress on working memory errors, individuals with BPD had superior working memory performance compared to the sample mean. This observation seems to contradict research findings suggesting impairments in WM in individuals with BPD.

To date, only a few studies have focused on WM difficulties when processing *emotional information*. One study by Krause-Utz and colleagues (2012) examined neural activity in interpersonally traumatized BPD individuals using functional magnetic resonance imaging (fMRI) during an emotional working memory task. The WM task required participants to hold information online in WM (e.g., a set of letters or negative interpersonal pictures) while ignoring emotional or neutral distracters. The findings showed that individuals with BPD had longer reaction times and higher activation in the amygdala and insula when presented with emotional distractors compared to healthy individuals (Krause-Utz et al., 2012). This suggests that BPD is associated with increased attention to task-irrelevant (emotional) social information during a working memory task. In another study, Krause-Utz and colleagues (2014) investigated the impact of social cues (neutral vs. negative) on WM performance in BPD

patients compared to healthy individuals. Participants performed an emotional version of Sternberg item recognition task while being distracted by neutral or negatively arousing pictures (faces and interpersonal scenes) and also reported their aversive inner tension. Results showed decreased accuracy after a distraction by negatively arousing social cues and negative correlations between accuracy and inner tension in BPD individuals. Finally, in a recent study, Krause-Utz and colleagues (2020) examined whether training emotional working memory influences how individuals with BPD regulate their emotions. The participants took part in a 28-day training using an adapted n-back task with emotional facial expressions (negative vs. neutral), and auditory words (negative, positive, and neutral) as distractors. The results indicated that the training enhanced emotional WM performance and improved cognitive reappraisal in individuals with BPD. However, improvements in cognitive reappraisal were also observed in the control group. These findings indicate that emotional working memory operations can be ameliorated by extensive cognitive training methodologies and may be related to emotion regulation.

Although research has made initial advances in understanding WM difficulties when processing emotional information and responding to stressful contexts in BPD, much has yet to be understood about the nature as well as the role of emotional WM in BPD. There is a need for studies to substantiate and extend initial observations on emotional WM operation in BPD. That is, to characterize the nature of emotional WM in BPD, it seems important to distinguish individuals with vs. without NSSI. It has been proposed that NSSI subgroups may have distinct difficulties in executive functions (Vega, et al., 2015; Fikke, Melinder, & Landro, 2011). It is then possible that the nature of emotional WM operations (e.g., updating and manipulating the emotional information held online in WM over a short time interval) differs between individuals with BPD according to the presence of NSSI. Indeed, NSSI is often triggered by interpersonal rejection and invalidating situations in individuals with BPD (Snir et al., 2015; Turner et al.,

2016). Therefore, identifying mechanisms that may differentiate persons with vs. without NSSI may aid a better understanding of one of the most harmful emotional responses in BPD. Moreover, research has yet to investigate the relationship between emotional WM operations and individual differences in rejection sensitivity. This knowledge seems important to understand which trait factors modulate how interpersonal information is processed. Finally, given that prior work focused on general WM impairments, studies have yet to examine how social stress impacts emotional WM operations in BPD. The current study was designed to address these open questions and improve the understanding of how individuals reporting various levels of BPD symptoms process emotional information.

Based on prior work (e.g., Krause-Utz et al. ,2012), this study hypothesized that individuals with BPD features have greater difficulties in updating emotional WM representations compared to individuals without BPD features. No strong a-priori predictions were made as to whether individuals with BPD and NSSI would differ from individuals with BPD features but without NSSI with respect to emotional WM operations. Moreover, it was expected that higher levels of rejection sensitivity would be related difficulties in discarding and entering emotional WM operations. Finally, it was anticipated that social stress elicited by a social exclusion experiences would increase difficulties updating emotional WM content.

2. Method

2.1. Participants

Undergraduate students (n=1687) from three universities in [MASKED] (ages between 18 to 24) were prescreened for BPD features using the Personality Assessment Inventory-Borderline Features (PAI-BOR; Morrey, 1991). A total of 1405 students (830 females) provided valid data. Of these participants, 13.3% reported elevated scores for the PAI-BOR in this study, which is comparable to previous research (e.g., Morey et al., 2014). Individuals who scored above 38 on the PAI, a cutoff indicating the presence of clinically significant BPD symptoms

(Morey, 1991; Trull, 1995; Trull et al., 1997), were invited for a clinical interview via telephone. The telephone interview included the SCID-II module for BPD to confirm the presence of BPD features as well as the Self-Injurious Thoughts and Behaviors Interview (SITBI) to determine self-injurious thoughts and behaviors. A trained and registered clinical psychologist performed all telephone interviews. Two groups with BPD features were created: A first group (BPD + NSSI history) consisted of individuals with BPD features (PAI-BOR score>38) who had injured themselves (NSSI history) at least two times in the past two years (n=40; cf. Muehlenkamp, Ertelt, Miller, & Claes, 2012). The second group (BPD – NSSI) included individuals with BPD features that did not report an NSSI history (n= 49). The mean score of BPD features on the PAI-BOR was 46.37 for individuals with BPD+NSSI (SD= 6.23; range: 39-58); and 44.34 for individuals in BPD-NSSI group (SD=4.85; range: 38-57). From the pool of 1405 students who completed the PAI-BOR, individuals with PAI-BOR scores below the cutoff point and no lifetime NSSI (n=786) were invited for a clinical interview. The interview included the SCID-I modules for mood disorders and anxiety disorders as well as the SCID-II the modules for BPD. Of the participants who agreed to participate in the interview (n=123), 47 did not suffer from any mood, anxiety, and borderline personality disorders, so they qualified for inclusion in the healthy group. Individuals in this group did not have any features of BPD (PAI-BOR scores between 8 to 22), NSSI history, or diagnosis of psychological disorder (n= 47). The inclusion criteria applied to all groups were (1) age between 18 to 24 years old; (2) fluency in the Persian language; (3) not under the influence of substances or antipsychotic medication. The current study was approved by the [MASKED] University Research Ethical Committee.

2.2. Procedure

Participants were completed two sessions. In the first session, all participants executed the emotional n-back task to measure WM updating operations in response to emotional

information. Participants were seated behind a computer at approximately 60 cm from the screen. Responses were recorded using response boxes. Next, they completed the Rejection Sensitivity Questionnaire (RSQ; Downey & Feldman, 1996). Fainlly, participants were told that they would receive feedback on the n-back task performance one week later (second session). This manipulation is in line with prior work (e.g., Baumeister, DeWall, Ciarocco, & Twenge, 2005; Baumeister, Twenge, & Nuss, 2002; DeWall & Baumeister, 2006; Twenge et al. 2001) and served to potentiate effects of the social exclusion manipulation (see below). In the second session, participants first received artificial feedback (see below) and played the Cyberball game to induce social exclusion (Williams & Jarvis, 2006). Immediately after the Cyberball game, participants completed the emotional n-back task and filled out the RSQ. Participants were fully debriefed at the end of the session and compensated for their participation ($10 for each participant).

2.3. Social Exclusion Induction

In line with prior research (Baumeister et al., 2005; DeWall et al., 2006; Twenge et al., 2001), participants received artificial feedback at the start of the second lab session to increase sensitivity to social rejection during the upcoming Cyberball game. Participants were told this feedback was based on their responses to the task and questionnaires from the first session. The following feedback was provided to all participants (copied from Twenge et al., 2001):

You are the person who will end up alone later in life. You may have friends and relationships now, but by your mid 20's most of these will have drifted away. You may even marry or have several marriages, but these are likely to be short-lived and not continue into your 30's. Relationships do not last, and when you are past the age where people are continually forming new relationships, the odds are you will end up being alone more and more.

After reading the feedback, participants started the Cyberball game (Williams & Jarvis, 2006). Cyberball is a computer-based behavioral task aimed to assess the effects of inducing

social exclusion. Participants were told they were playing with two other students from around campus. They were led to believe that they are logged on simultaneously with two others and were told that to stimulate mental visualization skills, they would perform a virtual ball-tossing game (Rennenberg et al., 2012). In reality, no other participants were involved, and the computer controlled the two agents involved in the game.

To support this cover story, the experimenter made two fake phone calls to one of the other laboratories involved in this study. Both calls were made in the room with the actual participant, and in both calls, the experimenter pretended to ask whether the other participants were ready, made a comment about it being good that everyone arrived on time, and stated that, should there be any problems, they could call back at the experimenter's number.

At the introduction of the Cyberball task, participants were informed that they were represented by an animated figure at the bottom of the screen, whereas the two other players were represented by animated figures located above and to the right and left of the participant's figure. Participants were instructed to click on one of the two figures to throw them the ball throughout the task (Bernstein and Claypool, 2012). They should imagine the whole tossing situation. To induce rejection, the participants received the ball twice during the first ten ball-throws. After that, they were excluded and were able only to watch the others playing. In this condition, the total number of throws was 30. The entire playing time, including the instructions, lasted about 3 to 5 minutes. Several previous studies have examined the effectiveness of Cyberball as a social rejection manipulation (Williams & Jarvis, 2006), and a meta-analysis suggests the effect on experiencing ostracism/rejection is large and stable (Hartgerink, van Beest, Wicherts, & Williams, 2015).

2.4. Emotional N-back task

2.4.1. Stimuli

Images of happy, angry, and neutral faces were drawn from the Radboud Faces Database (Langner, Dotsch, Bijlstra, Wigboldus, Hawk, & van Knippenberg, 2010). The 4 happy, 4 angry and 4 neutral faces were matched on intensity of valence (M_{happy} = 3.5, SD = 0.4; M_{angry} = 4.1, SD = 0.4; $M_{neutral}$ = 3.4, SD = 0.3). Additionally, four images of physical pain faces were selected from the STOIC Dynamic Facial Emotional Expressions Database (Roy et al., 2007). The 16 images displayed expressions by six different actors and eight females. We used angry faces to signal social rejection, happy faces to signal social acceptance, and pain faces to signal physical pain (potentially related to NSSI).

2.4.2. Experiment task

An emotional 2-back task (e.g., Everaert, Grahek, & Koster, 2016; Levens & Gotlib, 2010) is a continuous performance task used to examine WM updating operations for various types of emotional information (cf. the angry, pain, happy, and neutral facial stimuli). In this task, face images were successively presented, and participants indicated whether the current facial expression was the same (match trials) or different (no-match trials) as two trials back. Face images were presented in random order. Male and female pictures were presented in different experimental blocks. Emotional valence was varied randomly within each block. Each face image was presented for 500 ms with inter-trial intervals between 800-1200 ms. For the first two faces in each block, participants were asked to view the faces without pressing a key. Participants first completed a 12-trial practice block. This was followed by 216 experimental trials in 10 blocks (four blocks each containing 30 trials, and six blocks each containing 16 trials) in which two or three different emotional expressions were presented mixed (i.e., pain/anger/neutral, pain/happy/neutral, anger/happy/neutral, pain/anger/happy, pain/anger, pain/happy, anger/happy, anger/neutral, pain/neutral, happy/neutral). These blocks were presented randomly.

Updating indices. The 2-back task requires participants to enter a new stimulus into WM while discarding an older stimulus to compare the current stimulus to the stimulus presented two trials earlier. There were sixteen trial types based on the updating operation (enter, discard) and the valence of the stimulus (angry, pain, happy, neutral). Indexes for updating in response to angry, pain, and happy stimuli were calculated using match and no-match trials. Separate indices for discarding and entering operations were computed based on trials with correct responses. The following trials were used to compute the WM updating indices: discard-neutral/enter-neutral trials, discard-angry/enter-neutral, discard-pain/enter-neutral, discard-happy/enter-neutral, discard-neutral/enter-angry, discard-neutral/enter-pain, discard-neutral/enter-happy. For angry faces, a WM discarding index was computed by subtracting reaction times on discard-neutral/enter-neutral trials from reaction times on discard-angry/enter-neutral trials. A higher score reflects a slower discarding of angry faces from WM. A WM entering index was computed by subtracting reaction times on discard-neutral/enter-neutral trials from reaction times on discard-neutral/enter-angry trials. Again, a higher score reflects a slower entering of angry faces in WM. This procedure was repeated for pain and happy faces.

2.5. Self-report measures

2.5.1. Personality Assessment Inventory–Borderline Subscale (PAI-BOR)

The PAI-BOR (Morey, 1991) consists of 24 items with four subscales representing core features of BPD. These subscales include Affective Instability, Self-harm/Impulsivity, Interpersonal Relationships, and Identity Problems. The PAI-BOR consists of items that directly map on to DSM–5 diagnostic criteria for BPD (e.g., DSM–5: chronic feelings of emptiness; PAI-BOR: “Sometimes I feel empty inside”) and items that describe features relevant but not identical to these criteria (e.g., PAI-BOR: “People once close to me have let me down”). The items can be answered on a Likert scale from 0 (false) to 3 (very true). Studies

have demonstrated good validity and reliability for the use of the PAI-BOR in nonclinical samples (Trull, 1995; Trull et al., 1997). The PAI-BOR inventory has been translated in [MASKED], which also has good concurrent validity (the correlation coefficients ranged between 0.68 to 0.89) in an [MASKED] sample [MASKED]. In the current sample, the PAI-BOR demonstrated good internal consistency, with Cronbach's α for the subscales ranging between 0.67 and 0.89.

2.5.2. Self-injurious Thoughts and Behaviors Interview (SITBI)

The SITBI (Nock, Holmberg, Photos, & Michel, 2007) is a structured interview that assesses the presence, age of onset, frequency, and severity of suicide-related thoughts and behaviors, such as suicide attempts, gestures, plans, ideation, and NSSI. In past studies, the SITBI has demonstrated strong inter-rater reliability and test-retest reliability, as well as strong concurrent and convergent validity (Nock et al., 2007). In the present study, we used SITBI to identify students with non-suicidal self-injury and assign them to the groups. Specifically, we selected students who injured themselves at least two times in the past two years.

2.5.3. Rejection Sensitivity Questionnaire (RSQ)

The RSQ (Downey & Feldman, 1996) is an 18-item questionnaire with self-report items. It presents scenarios in which people are susceptible to rejection by an important other. Individuals are asked to rate their phase of concern related to potential rejection on a 6-point Likert scale (1 = very unconcerned; 6 = very concerned) and are then asked to estimate the likelihood that a significant other will respond favorably to them on a 6-point Likert scale (1 = very unlikely; 6 = very likely). After calculating the rejection sensitivity score for each question (Downey & Feldman, 1996), the rejection sensitivity scores are averaged across all 18 situations to gain a total Rejection Sensitivity Score. Higher scores on the RSQ indicate greater sensitivity to rejection. The RSQ demonstrated acceptable internal consistency ($\alpha = 0.85$) in our research.

Previous studies have shown high test-retest reliability (r = 0.83 after two to three weeks follow-up; Downey & Feldman, 1996).

2.5.4. Beck Depression Inventory-II (BDI-II)

The BDI-II (Beck, Steer, & Brown, 1996) was used to measure depression symptoms. It is a 21-item self-report questionnaire designed to assess levels of depression in nonclinical populations. Item scores range from 0 (low intensity) to 3 (high intensity). It has been demonstrated to be a valid and reliable measure of depression (Beck et al., 1996). The Persian version of BDI-II has high internal consistency (Cronbach's α=0.87) and acceptable test-retest reliability (r=0.74) [MASKED].

2.5.5. Beck Anxiety Inventory (BAI)

The BAI (Beck & Steer, 1990) is a 21-item self-report instrument for measuring the severity of anxiety. The BAI focused on unique features of anxiety; 14 of its items represent somatic symptoms, whereas the remaining seven symptoms reflect specific cognitions associated with the subjective aspects of anxiety. In using the BAI, subjects rate the severity of each symptom on a four-point scale ranging from (0) "Not at all" to (3) "Severely- I could barely stand it." The inventory possesses high internal consistency (alphas of 0.92 and 0.94) and test-retest reliabilities of 0.73, according to Fydrich, Dowdall, Chambless (1992). The BAI displays high concurrent validity with other self-report and clinical rating scales of anxiety. For example, Beck, Epstein et al. (1988) found that it correlates 0.51 with the revised Hamilton Rating Scale for Anxiety (Riskind, Beck, Brown, & Steer, 1987), and Fydrich et al. (1992) reported that it correlates 0.58 and 0.47, respectively, with the Trait and State scales of the State-Trait Anxiety Inventory. The Persian version of BAI proved excellent validity (r=0.83). It was correlated with the Persian version of the Hamilton Rating Scale. BAI also showed excellent internal consistency (Cronbach's α=0.92) in an [MASKED] sample [MASKED].

2.5.6. Manipulation Check

After completing the study, participants were asked the following question about the Cyberball task: “Did you feel that the other players included you or excluded you in the game?” All participants (even in the healthy group) confirmed that they experienced rejection after doing the ball-tossing game.

2.6. Data preparation and analyses

Before analyzing the n-back task, the raw reaction time (RT) data was cleaned. RTs faster than 100 ms were first excluded. Then, interquartile ranges (IQR) were calculated for each individual to identify within-participant outliers. Observations more than 1.5*IQR below the first quartile or 1.5*IQR above the third quartile were removed. A total of 0.9% of the data at testing phase 1 (before inducing social exclusion) and 1.2% at testing phase 2 (after inducing social exclusion) were excluded.

We first started with analyses of emotional WM updating operations in relation to BPD features at baseline using the one-way ANOVA. Second, we examined emotional WM updating operations in relation to individual differences in rejection sensitivity using Pearson correlation. Then, changes in rejection sensitivity in response to social exclusion calculated by the 2 (Time: before and after inducing social exclusion) by 3 (Group: control, BPD features without NSSI, BPD features with NSSI) repeated measures ANOVA on rejection sensitivity scores. Finally, changes in emotional WM updating concerning social exclusion induction were investigated by the 2 (Time: before and after inducing social exclusion) by 3 (Valence: angry, pain, happy) by 3 (Group: control, BPD features without NSSI, BPD features with NSSI) repeated measures ANOVA on the WM entering and discarding operations. Assumptions for running ANOVAs were checked and met.

3. Results

3.1. Descriptive Information

The mean age of participants in the BPD features without NSSI history, BPD features with NSSI history, and the healthy groups was 20.04 (*SD*=1.64), 19.77 (*SD*=1.04), and 19.61 (*SD*=1.41), respectively. The gender distribution was not significantly different between the groups (χ^2*=2.29; p=.320*; see Table 1). Moreover, no significant group difference emerged with respect to depression (*F*(2,129)=2.21; *p*=.113) and anxiety (*F*(2,129)=1.77; *p*=.174) symptoms (see Table 1).

3.2. Group differences concerning Emotional WM updating

As shown in Table 2, significant group differences were observed for WM discarding operations for angry and pain faces, as well as WM entering operations for happy faces. No significant group differences emerged for discarding operations for happy faces or entering operations for angry, and pain faces.

Planned contrasts revealed that the BPD features group with NSSI, t(127)=2.70, p=.008, and the BPD features group without NSSI, t(127)=4.03, p<.001, were slower at *discarding angry* faces from WM compared to the control group. The difference between the BPD features groups was not statistically significant, t(127)=1.16, p=.247. Regarding *discarding pain* faces from WM, the BPD features group with NSSI, t(128)=4.78, p<.001, and BPD features group without NSSI, t(128)=3.30, p=.001, were slower compared to the control group. Again, no differences emerged between the BPD features groups, t(128)=1.65, p=.101. Finally, regarding *entering happy* faces into WM, the BPD features group with NSSI was significantly slower compared to the BPD features group without NSSI, t(60.46)=2.37, p=.021, and the control group, t(56.40)=2.38, p=.021. No significant difference occurred between the BPD features group without NSSI and the control group, t(87.72)=0.07, p=.845.

3.2. Associations between rejection sensitivity and emotional WM updating

Correlational analyses examined associations between WM updating and individual differences in rejection sensitivity. As shown in Table 3, *discarding angry* faces from WM was

positively correlated with rejection sensitivity, r=.36, p<.001. Likewise, *discarding pain* faces was related to rejection sensitivity, r=.33, p<.001. No other correlations reached the .05 threshold for statistical significance. This pattern of correlations suggests that higher levels of rejection sensitivity are related to slower discarding of angry and pain faces from WM.

3.3. Changes in emotional WM updating in relation to social exclusion induction

3.3.1. Manipulation check: Changes in rejection sensitivity

The results of the 2 (Time: before and after inducing social exclusion) by 3 (Group: control, BPD features without NSSI, BPD features with NSSI) repeated measures ANOVA on rejection sensitivity scores revealed significant main effects of Time, F(1, 129)=124.34, p<.001, partial η^2=.491, and Group, F(2, 129)=218.20, p<.001, partial η^2=.772, which were qualified by a Time by Group interaction effect, F(2, 129)=44.77, p<.001, partial η^2=.410. Follow-up analyses revealed that there were significant increases in rejection sensitivity in the BPD features group without NSSI, F(1, 46)=51.98, p<.001, partial η^2=.531, as well as in the BPD features group with NSSI, F(1, 38)=91.80, p<.001, partial η^2=.707. No significant changes occurred in the control group, F(1, 45)=0.72, p=.400, partial η^2=.016. For means, see Table 4.

3.3.2. Changes in emotional WM discarding and entering operations

WM discarding. The 2 (Time: before and after inducing social exclusion) by 3 (Valence: angry, pain, happy) by 3 (Group: control, BPD features without NSSI, BPD features with NSSI) repeated measures ANOVA on WM discarding operations yielded significant main effects of Valence, F(2, 113)=3.84, p=.024, partial η^2=.064, and Group, F(2, 114)=6.56, p=.002, partial η^2=.103, as well as a Valence by Group interaction, F(4, 228)=6.12, p<.001, partial η^2=.097. Of interest to this study, the three-way interaction of Time by Valence by Group was not significant, F(4, 228)=1.67, p=.158, partial η^2=.028. None of the other effects related to Time were statistically significant: Time, F(1, 114)=2.38, p=.126, partial η^2=.020, Time by Group, F(2, 114)=2.15, p=.121, partial η^2=.036, and Time by Valence, F(2, 113)=1.59, p=.210, partial

η^2=.027. These results suggest that there were no group differences in the change in WM discarding operations on anger, pain, and happy faces in response to the social exclusion manipulation.

WM entering. The 2 (Time: before and after inducing social exclusion) by 3 (Valence: angry, pain, happy) by 3 (Group: control, BPD features without NSSI, BPD features with NSSI) repeated measures ANOVA on WM entering operations produced significant interaction effects of Time by Group, F(2, 115)=4.16, p=.018, partial η^2=.067, and Valence by Group, F(4, 230)=2.71, p=.031, partial η^2=.045. However, the three-way effect of Time by Valence by Group was not significant, F(4, 230)=1.85, p=.120, partial η^2=.031. Furthermore, there were no significant main effects of Time, F(1, 115)=0.01, p=.919, partial η^2=.000, Valence, F(2, 115)=2.30, p=.105, partial η^2=.039, or Group, F(2, 115)=1.04, p=.358, partial η^2=.018, or significant interaction effects of Time by Valence, F(2, 114)=1.33, p=.268, partial η^2=.023. These findings indicate that no group differences emerged in the change in WM entering operations on anger, pain, and happy faces in response to the social exclusion manipulation.

4. Discussion

This study examined emotional WM operations concerning BPD features in the context of social exclusion. The main results showed that participants with BPD features were slower at discarding angry and pain faces from WM compared to healthy individuals at baseline. Participants with BPD features and a self-injury history were also slower at entering happy faces into WM compared to the other participants; higher levels of rejection sensitivity were related to slower discarding of angry and pain faces from WM (across all participants); and finally, there were no group differences in the change in WM entering and discarding operations for angry, pain, and happy faces in response to the social exclusion manipulation.

This study observed specific WM difficulties linked to BPD features. When processing angry stimuli and pain stimuli, WM discarding operations were slower in individuals reporting

BPD features (regardless of their NSSI history). WM entering operations were generally intact except when individuals with BPD features and a history of NSSI were processing happy faces. These findings are in line with emerging research documenting BPD-related difficulties in WM when processing emotionally neutral material (Lazzaretti and colleagues, 2012; Stevens et al., 2004; Hagenhoff et al., 2013). Importantly, the findings of this study add to observations that were reported by prior studies using an *emotional* working memory task (Krause-Utz et al., 2012, 2014). This research found increased attention to task-irrelevant social-emotional information during a WM task in BPD patients. Our study extends this work by documenting BPD-linked difficulties in specific WM operations (discarding, entering) and emotional content (sad, angry, and happy face stimuli) according to one's history of self-injury. Indeed, the combination of difficulties in discarding negative interpersonal information from WM (and, for individuals with a history of NSSI, entering positive information into WM) may help to understand critical features of BPD, such as the sensitivity to signs of social rejection.

This study observed that higher levels of rejection sensitivity were related to slower discarding angry and pain faces from WM. This finding is consistent with the notion that individuals with a higher level of rejection sensitivity may excessively focus their cognitive resources on threat cues as a mechanism for detecting and dealing with possible rejection (Sato et al., 2018). WM difficulties could further elevate rejection sensitivity in BPD by maintaining negative interpersonal information in WM and occupying cognitive resources. In this way, WM difficulties could be an essential cognitive mechanism for maintaining BPD features. It is to note that this is the first study demonstrating associations between emotional WM operations and rejection sensitivity in individuals with BPD features, and further research is required to understand the role of working memory difficulties in BPD better.

A final observation of this study was that no differences emerged between BPD features groups in the change in both WM entering and discarding operations on anger, pain, and happy

faces in response to social exclusion induction. Note that WM operations did not significantly change, whereas there were significant increases in rejection sensitivity to the social exclusion manipulation. While Bellovin-Weiss (2014) found that emotional distress can impact WM capacity, our findings indicate that WM difficulties may not be reactive to social exclusion in BPD. One reason for the absence of WM differences before and after the social exclusion in relation to BPD symptoms is that individuals with elevated BPD symptoms already have elevated state levels of social exclusion at entry of the experiment, rendering the social exclusion induction less effective (see also Bungert et al., 2015). Another reason for the absence of effects is that the absence of differences before and after social exclusion are partially explained by learning effects that were manifested at second testing of WM. While prior work has utilized emotionally neutral stimuli, further research is needed to examine emotional WM operations under the condition of interpersonal stress.

This study has implications for the delivery of cognitive training methods to target BPD features. If research further supports the notion that emotional WM operations are causally related to BPD symptoms, research could examine whether cognitive interventions targeting WM operations to ameliorate key features of BPD, including rumination and rejection sensitivity.

Several limitations to this study need to be acknowledged. First, we used an undergraduate sample with BPD features with and without NSSI behaviors. Although a substantial proportion demonstrated clinical BPD levels, the results of our study may not generalize to patient populations, and clinical follow-up work in this era is needed. Second, we did not consider the comorbidity of BPD with other disorders. Taking the comorbid disorders with BPD into account can help researchers to determine whether the cognitive profiles of these disorders are distinct or not. Such information may pave the way for cognitive rehabilitation of BPD individuals suffering from comorbid disorders. Thus, future studies need to replicate our

findings in larger samples that allow considering comorbidities to explore if WM updating operations are specific to this disorder. While, the within-subjects approach allowed to assess emotional WM operations at baseline and under social exclusion, the repeated administration of the emotional n-back task may have introduced practice effects that obscure the impact of social exclusion on WM performance. Finally, data to examine relations between BPD features, rejection sensitivity, and (baseline) emotional WM operations were collected at a single time point, which precludes claims about the directionality of effects. Further research could implement the longitudinal design to determine whether WM difficulties influence and/or are influenced by rejection sensitivity as well as BPD symptoms.

In sum, the current study was designed to investigate emotional working memory updating operations in individuals with BPD features with and without NSSI. The results of this study revealed specific WM difficulties in discarding and entering of emotional information related to both BPD and rejection sensitivity. In addition, this study did not find changes in WM performance in response to a social exclusion induction and follow-up work could explore to what extent emotional WM difficulties are reactive to social exclusion.

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Table 1. Demographic and clinical characteristics of the groups.

	BPD features with NSSI	BPD features without NSSI	healthy group
Gender distribution (f/m)	18/21	29/18	27/19
BAI	13.72 (5.97)	12.66 (6.36)	11.20 (6.27)
BDI-II	12.79 (5.44)	13.49 (4.94)	11.46 (3.73)

Table 2. Group differences in WM performance (reaction times in ms) at testing phase 1 (baseline)

	Control		BPD - NSSI		BPD + NSSI		
	M	SD	M	SD	M	SD	
Discard Angry	-200	244	42	299	-30	318	F(2,127)=8.45, p<.001
Discard Pain	-156	247	29	263	126	300	F(2,128)=12.04, p<.001
Discard Happy	-89	193	-55	230	-97	331	Welch's F(2,73.16)=0.36, p=.701
Enter Angry	-79	205	-30	230	-7	252	F(2,126)=1.08, p=.342
Enter Pain	-70	156	-12	156	16	232	Welch's F(2,79.13)=2.54, p=.086
Enter Happy	-58	142	-60	165	57	270	Welch's F(2,77.07)=3.14, p=.049

Note. Welch's robust tests of equality of means were reported for Discard Happy, Enter Pain, and Enter Happy because the homogeneity of variance assumption was violated.

Table 3. Correlational analyses.

	Rejection Sensitivity	
	r	p
Discard Angry	.36	.000
Discard Pain	.33	.000
Discard Happy	.03	.752
Enter Angry	.10	.241
Enter Pain	.15	.082
Enter Happy	.15	.098

Table 4. Means and standard deviations for the WM task before and after the Cyberball

	Control Group				BPD - NSSI				BPD + NSSI			
	Testing phase1		Testing phase2		Testing phase1		Testing phase2		Testing phase1		Testing phase2	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Discard Angry	-200	244	-94	206	42	299	65	226	-30	318	-26	258
Discard Pain	-156	247	-67	209	29	263	33	253	126	300	17	286
Discard Happy	-89	193	-55	131	-55	230	-49	171	-97	331	-38	244
Enter Angry	-79	205	-22	154	-30	230	-98	125	-7	252	-25	299
Enter Pain	-70	156	-4	108	-12	156	14	143	16	232	-116	246
Enter Happy	-58	142	13	129	-60	165	1	123	57	270	-3	172
Rejection sensitivity	84	26	87	25	178	36	192	37	184	34	228	23