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THE STATISTICAL SPECIFICITY OF EMOTION DYNAMICS IN BORDERLINE PERSONALITY DISORDER

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Persons with borderline personality disorder (BPD) experience heightened emotional instability. Different components underlie instability, and the relation between instability and well-being could be confounded by average emotionality and within-person standard deviation across emotional states, reflecting variability. Therefore, the goal was to examine which pattern of emotion dynamics parsimoniously captures the emotional trajectories of persons with BPD. Forty persons with BPD, 38 clinical controls in a major depressive episode, and 40 healthy controls rated the intensity of their emotions 10 times a day for 1 week. After correction for differences in average emotionality, persons with BPD showed heightened emotional instability compared to both control groups. When additionally correcting for emotional variability, the authors found that instability indices did not differ between groups anymore. This shows that persons with BPD differ from control groups in the magnitude of emotional deviations from the emotional baseline, and not necessarily in the degree of abruptness of these deviations.

Keywords: emotion dysregulation, emotional instability, borderline personality disorder, statistical specificity, emotion dynamics

Borderline personality disorder (BPD) is a serious mental disorder that poses a large burden on individuals and society. It is characterized by instability in affect, identity, and interpersonal relations, by impulsivity and potentially self-harming behavior, and by suicidality (American Psychiatric Association, 2013). Because of the pervasiveness of the features and high suicide risks associated with BPD (Leichsenring, Leibing, Kruse, New, & Leweke, 2011), BPD is linked to intense use of mental health care and large societal costs (van Asselt, Dirksen, Arntz, & Severens, 2007). Despite the heterogeneity of the different features, emotion dysregulation is often assumed to be the core feature of the disorder (Carpenter & Trull, 2013; Linehan, Bohus, & Lynch, 2007).

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EMOTION DYSREGULATION IN BPD

According to the biosocial theory of BPD (Crowell, Beauchaine, & Linehan, 2009; Linehan et al., 2007), BPD is a disorder of emotion dysregulation. It develops as a result of biological vulnerability for poor impulse control and emotional sensitivity (Crowell et al., 2009), in combination with an invalidating developmental context in which a child does not properly learn to understand, label, and regulate emotions and to control emotional responses. The reciprocal transaction between these two factors fosters and reinforces emotional lability, the core feature of BPD, which leads to dysregulated behavioral and cognitive reactions to emotional situations. With frequent repetition, these reactions result in traitlike emotion dysregulation and persistent negative outcomes in the cognitive, social, behavioral, and emotional domains. These reactions are also reinforced over time by their use as ways of regulating or avoiding emotions.

In order to obtain more insight into the nature of this dysregulation and its manifestation in daily life, in the past few decades numerous studies have examined how emotions unfold over time in the daily life of persons with BPD. This is typically done using experience sampling methods (ESM) or ecological momentary assessment (EMA), in which participants carry an electronic device during their everyday activities that they use to repeatedly assess their current emotional states multiple times a day for many consecutive days. Repeated emotion ratings can then be used to explore patterns with which emotions change and fluctuate over time. Such patterns are often referred to as emotion dynamical patterns (Houben, Van Den Noortgate, & Kuppens, 2015) and are assumed to be a joint result of emotional challenges that people encounter and the way people emotionally deal with these challenges. As a result, such overall patterns of emotion dynamics can give clues to how people function emotionally in daily life. In the past few decades, two different patterns of emotion dynamics have been consistently and positively associated with a diagnosis of BPD: patterns capturing emotional variability, and patterns capturing emotional instability (Houben et al., 2015).

EMOTION DYNAMICS IN BORDERLINE PERSONALITY DISORDER

The first pattern that has been linked to BPD is the pattern of *emotional variability* (Russell, Moskowitz, Zuroff, Sookman, & Paris, 2007; Stein, 1996). Emotional variability capture emotions that deviate strongly from the average emotional state of a person over time. This is typically measured using the within-person standard deviation of repeated emotional assessments over time. As a consequence, emotional variability takes into account the overall degree of deviation from the emotional baseline, but it neglects the temporal aspect of these changes. This means that strong deviations from the baseline that follow a U-shaped curve and strong deviations that follow a cyclic pattern characterized by frequent ups and downs could result in a similar degree of emotional variability.

Because of this shortcoming, new measures were developed that do take the temporal aspect of changes into account by quantifying the degree of emotional change from one moment to the next. Examples of such measures that have been linked to BPD are the mean squared successive differences or mean absolute successive differences (MSSD or MASD; Ebner-Priemer et al., 2007; Santangelo et al., 2014; Trull et al., 2008), the probability of acute change, defined as consecutive changes that are within the 10% largest changes (e.g., Santangelo et al., 2014; Trull et al., 2008), and the magnitude of consecutive emotional changes if a switch between a positive and negative emotional state occurred (i.e., emotional switches; Houben, Vansteelandt, et al., 2016). These measures are sensitive to the temporal aspect of emotional changes, and therefore are assumed to capture the degree of *emotional instability*. As illustrated in Figure 1, large emotional changes around the emotional baseline that follow an abrupt up-and-down pattern would result in high levels of emotional instability and variability, while large changes that follow a more gradual U-shaped pattern over time would result in large variability but relatively lower instability. In the past decade, studies examining patterns of emotion dynamics in relation to BPD have emphasized that emotional instability is the defining feature of persons with BPD, highlighting the importance of abrupt emotional changes from one moment in time to the next. These findings are in line with emotional instability being one of the defining features of the disorder (American Psychiatric Association, 2013).

STATISTICAL SPECIFICITY OF EMOTION DYNAMICS IN BPD

However, measures of emotional variability and instability are statistically and conceptually closely related. For example, Jahng, Wood, and Trull (2008) have shown that the most commonly used index of emotional instability, the MSSD, can statistically be expressed as a function of (a) the within-person standard deviation of repeated emotional states over time, capturing emotional variability, and (b) the inverse of the autocorrelation/emotional inertia (Jahng et al., 2008). This second component reflects the degree of resistance to change and thus reflects the temporal aspects of the changes. As a result, patterns of strong emotional instability are a result of (a) strong emotional variability or strong overall deviations around the average emotional state of a person, (b) combined with weak emotional inertia, which reflects weak resistance to change. This implies that changes don't "stick," but occur quickly from one point to the next. Scholars in the field of emotion dynamics in BPD have postulated that exactly the combination of these two components, that is, strong deviations around the average emotional state that follow a cyclical pattern over time, characterize the emotion dynamics of people with BPD. In other words, it is assumed that emotional instability is the defining feature of BPD and that emotional variability alone cannot capture the true nature of emotion dynamics in BPD because the temporal aspect is not taken into account (Ebner-Priemer, Eid, Kleindienst, Stabenow, & Trull, 2009; Houben,

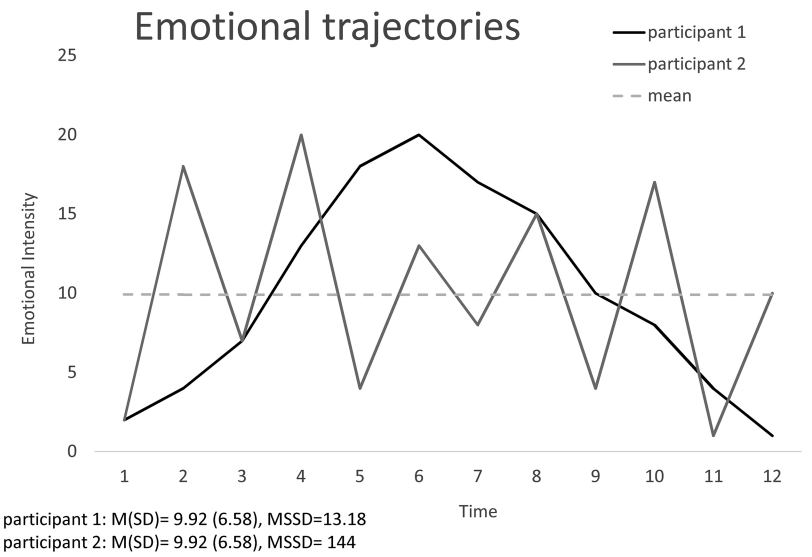


FIGURE 1. Figure illustrating the trajectory of two fictive persons characterized by the same average emotionality, as measured by the mean (*M*) across emotional states, and the same degree of variability, as calculated with a within-person standard deviation (*SD*), but different degrees of emotional instability, as measured by a mean squared successive differences (MSSD).

Vansteelandt, et al., 2016). Still, little to no empirical research has explicitly evaluated this claim using daily life methods.

Moreover, the idea that persons with BPD experience emotions that are characterized by fast alternations between emotional ups and downs is not necessarily in line with the biosocial theory (Crowell et al., 2009; Linehan et al., 2007). Linehan and colleagues postulate that the emotional vulnerability in BPD is characterized by several processes: Persons with BPD experience (a) heightened emotional sensitivity, which results in a lower threshold to respond to emotional stimuli; (b) heightened emotional reactivity to emotional stimuli, which results in emotional responses with greater amplitude; and (c) a slower return to baseline, which reflects weaker regulatory force to restore emotions to the baseline state. The combination of these processes would most likely result in a higher likelihood of responding to emotional triggers, in which the responses result in strong deviations from the baseline emotional state that tend to linger and show very slow emotional recovery. Such a profile would predict strong emotional variability around the baseline that does not follow a strong cyclical pattern. As a consequence, this emotional profile actually goes against the idea that persons with BPD show abrupt emotional ups and downs several times a day. Such a cyclical pattern would most probably be the result of strong emotional responses that deviate strongly from the baseline (i.e., emotional

"ups"), followed by a quick return to baseline (i.e., emotional "downs"), after which the emotional system is ready to respond to the next trigger.

Two daily life studies in which the three processes, as proposed in the biosocial theory (Crowell et al., 2009; Linehan et al., 2007), were simultaneously examined in persons with BPD support this idea. First, a study by Ebner-Priemer et al. (2015) examined differences between persons with BPD and healthy controls in terms of three fundamental processes that together capture the trajectory of emotional change over time (i.e., the DynAffect model; Kuppens, Oravecz, & Tuerlinckx, 2010): (a) the emotional homebase, which captures the usual or typical emotional state of a person, (b) the overall degree of deviations around this homebase, and (c) the attractor strength that reflects regulatory processes that enable recovery toward the homebase. The first component is both conceptually and statistically related to the mean of repeated assessment over time, the second to emotional variability, and the third to inertia/autocorrelation, capturing the temporal dependency of emotional changes. Moreover, all three processes map one-on-one onto the three processes proposed by the biosocial theory (Crowell et al., 2009; Linehan et al., 2007). Results from this study indicated that persons with BPD have a more negative and aroused emotional homebase and exhibit stronger deviations around this homebase. Some differences in attractor strength were observed between groups, but these were not robust and could not be replicated in all data sets that were examined. The differences that were observed pointed to a weaker attractor strength for persons with BPD, rather than a stronger one. This would again indicate that persons with BPD deviate strongly from their emotional homebase, then tend to stick in those aberrant emotional states for a while, and then slowly return to the emotional homebase. Such a profile is again not in line with an emotional profile in which frequent and fast sequences of ups and downs would be observed.

A second daily life study by Santangelo et al. (2016) used an almost identical approach but also included clinical control groups. When all clinical groups (including a BPD sample) were compared to healthy controls, very similar conclusions were obtained compared to the study by Ebner-Priemer et al. (2015). When persons with BPD were compared to the clinical control groups, some indications were found that persons with BPD have a homebase that is characterized by higher levels of distress. No convincing differences were observed for variability around the homebase and attractor strength. In sum, these two daily life studies that examined different components of emotional change over time also concluded that the differences between BPD and healthy controls were found mainly in terms of the emotional homebase (which reflects how people usually or typically feel) and in terms of the degree of variability or deviations around this homebase. The attractor strength, which captures the temporal aspect of changes, did not clearly differentiate between persons with BPD and healthy controls.

Additional indications that the true importance of emotional instability for BPD above and beyond more simple patterns of emotional variability should be verified comes from basic affective science. A recent study by Dejonckheere et al. (2019) has indicated that emotion dynamic measures in

daily life, including emotional instability indices such as the MSSD (related) measures, might add limited additional information for the prediction of a person's psychological well-being after considering the average emotion levels and the within-person standard deviation across emotional states (i.e., emotional variability; Dejonckheere et al., 2019; Houben & Kuppens, 2020). These authors argue that emotion dynamic patterns are closely related to these two more fundamental features of time-series data (i.e., average emotion levels and the within-person standard deviation across emotional states). To intuitively illustrate, very low and very high levels of average emotion can create a floor or ceiling effect, resulting in weaker emotional changes. Moreover, very large emotional changes around the baseline will automatically result in larger instability measures compared to such measures in a person with smaller changes around the baseline, even if in both cases these changes do not follow a strong cyclical pattern. As a consequence, in many cases, the relation between emotion dynamics and well-being can (in part) be explained by the relation between average emotion levels and variability on the one hand, and well-being on the other hand. In line with these new insights from affective research on emotion dynamics, it should therefore be verified whether the association between emotional instability and BPD is statistically robust against correction for these statistical features in order to correctly identify the true emotion dynamics involved in BPD.

THIS STUDY

The goal of this study was to explore the statistical specificity of emotional instability for BPD by correcting for statistical overlap with mean affect and within-person standard deviation (i.e., emotional variability), because these components could confound the relationship between emotional instability and BPD. This would elucidate whether abrupt consecutive changes are characteristic of people with BPD, or whether more fundamental parsimonious measures of emotional changes, such as mean affect and emotional variability, already capture the emotional trajectory of persons with BPD. When answering these questions, specific attention is given to the clinical specificity of the findings by comparing persons with BPD to a clinical control group and a healthy control group.

To answer this research question, we conducted an experience sampling study in which persons with BPD, clinical controls consisting of persons in a current major depressive episode but without BPD, and healthy persons rated their emotional experiences 10 times a day for 7 days. In a first step, we hypothesized that persons with a diagnosis of BPD would exhibit higher levels of emotional instability compared to clinical and healthy controls. Next, we hypothesized that after correcting for mean affect and within-person standard deviation of affective states, no differences between groups in terms of instability would be observed anymore. This would indicate that the relationship between emotional instability and BPD would be driven by worse average emotionality and stronger variability or deviations around the average emotional state over time.

METHOD

PARTICIPANTS

Our sample consisted of 40 persons with a diagnosis of BPD, 38 clinical controls without BPD who were currently experiencing a major depressive episode (MDE, with a diagnosis of either major depressive disorder [n = 34] or bipolar disorder [n = 4]), and 40 healthy controls (HC). Persons with an MDE were chosen as clinical controls because disturbed emotional experiences are also central in these patients. Participants with a clinical diagnosis were recruited through the University Psychiatric Center KU Leuven (departments of St. Anna and De Weg) or Broeder Alexianen Group Tienen (Prisma-II). The inclusion criterion was a diagnosis of at least one of the following: BPD, major depressive disorder, and/or bipolar disorder. Most patients took psychotropic medication (81% of the BPD group, with an average of 2.23 [*SD* = 1.50] different ones; 92% of the MDE group, with an average of 4.54 [*SD* = 2.59] different ones per person). Regarding BPD symptom severity, 20% of the BPD group scored within the average range, 40% within the high range, and 38% within the very high range, based on norm scores of the Assessment of *DSM-IV* Personality Disorders (ADP-IV)-Borderline Personality Disorder Scale (Schotte & De Doncker, 1996; Schotte, De Doncker, Vankerckhoven, Vertommen, & Cosyns, 1998). The average BPD score of the BPD sample was 53.97 (*SD* = 10.44), which is within the very high BPD score range. Regarding depression severity in the MDE sample, 5% of persons in the MDE group scored within the normal range, 11% within the mild range, 47% within the moderate range, 34% within the severe range, and 3% within the extremely severe range, according to clinical cutoffs of the depression subscale of the Depression Anxiety Stress Scales (DASS; Antony, Bieling, Cox, Enns, & Swinson, 1998; Lovibond & Lovibond, 1995). The average depression rating in the MDE group was 18.66 (*SD* = 5.10), reflecting a moderately depressed sample. Exclusion criteria were insufficient knowledge of Dutch, psychotic disorders, a primary diagnosis of substance abuse, being in an acute psychotic or manic phase, or the lack of sufficient cognitive abilities to use a smartphone to complete the experience sampling part. Comorbid diagnoses are reported in Table 1. For healthy participants, exclusion criteria were insufficient knowledge of Dutch, current or past diagnoses of psychiatric disorders, and the use of psychotropic medication. Healthy controls were recruited through advertisements, social media, and the Experiment Management System of the KU Leuven university.

All psychiatric inclusion and exclusion criteria for all groups were checked using Dutch translations of the Structured Clinical Interview for *DSM-IV* Axis I (Van Groenestijn, Akkerhuis, Kupka, Schneider, & Nolen, 1999) and Axis II Personality Disorders (Weertman, Arntz, & Kerkhofs, 2000). The average age was 31.5 years (*SD* = 11.14) for the BPD group, 40.61 years (*SD* = 13.79) for the MDE group, and 35.23 years (*SD* = 11.54) for the HC group. The MDE group was significantly older than the BPD group (mean difference = 9.11, *SE* = 2.76, p = .001), which was accounted for in all subsequent analyses. In the BPD group, 90% of participants were female. This percentage was lower in the MDE group (50%) and the HC group (58%); $\chi^2(2) = 15.91$, $p < .001$. As a consequence, we corrected for gender and age in subsequent analyses.

TABLE 1. Current Comorbid Diagnoses for Each Group

	BPD group (*N* = 40)		MDE group (*N* = 38)		HC (*N* = 40)	
	Frequency	%	Frequency	%	Frequency	%
Current depressive episode	20	50	38	100	0	0
Major depressive disorder	18	45	34	89	0	0
Bipolar disorder I or II	2	5	4	11	0	0
Obsessive-compulsive disorder	6	15	2	5	0	0
Generalized anxiety disorder	2	5	4	11	0	0
Posttraumatic stress disorder	7	18	0	0	0	0
Social phobia	3	8	3	8	0	0
Specific phobia	2	5	1	3	0	0
Panic disorder with agoraphobia	3	8	3	8	0	0
Panic disorder without agoraphobia	2	5	2	5	0	0
Agoraphobia without panic disorder	2	5	0	0	0	0
Anxiety NOS	0	0	2	5	0	0
Alcohol abuse	6	15	1	3	0	0
Alcohol dependence	2	5	1	3	0	0
Substance abuse	3	8	2	5	0	0
Substance dependence	2	5	2	5	0	0
Anorexia nervosa	1	3	1	3	0	0
Bulimia nervosa	3	8	0	0	0	0
Binge eating disorder	5	13	1	3	0	0
Brief psychotic disorder	2	5	0	0	0	0
Delusional disorder	1	3	0	0	0	0
Hypochondria	1	3	1	3	0	0
Borderline personality disorder	40	100	0	0	0	0

PROCEDURE

Ethical approval for this study was obtained by the Ethical Committee Research UZ/KU Leuven (S58526). At regular times, this study was presented to possible eligible patients during collective information sessions at the psychiatric institutes. Participants who showed interest in participation received more detailed information regarding the study in small groups, and they signed the informed consent form if they agreed to participate. Then they started the study. Healthy participants were informed about the study via online advertisements, and they could contact the researchers to receive more information and/or to sign up for the study. After signing the informed consent form, they were invited to the research lab to start the study.

The study consisted of four parts: Test Session 1, one week of experience sampling (ESM), Test Session 2, and online follow-up measurement after 6 months. For clinical participants, Test Sessions 1 and 2 took place in the psychiatric institute where they were recruited or in the research lab. Healthy participants were always tested in the research lab.

Test Session 1. First, the Structured Clinical Interview for *DSM-IV* Axis I (SCID-I) was completed to check inclusion and exclusion criteria. Second, participants completed a collection of self-report trait questionnaires and a computer task, which were collected for purposes unrelated to this study. Third, they received a research-dedicated phone that was programmed for the ESM part. Participants were trained in the use of the smartphone and received more information regarding the ESM questions.

Experience Sampling Week. For the ESM part of the study, participants received a Defy+ Motorola smartphone running mobileQ software (Meers, Dejonckheere, Kalokerinos, Rummens, & Kuppens, 2020). Participants first received two trial beeps in the evening of Session 1. The next day, the phone was programmed to emit a beeping alarm 10 times a day for 7 consecutive days between 9:30 a.m. and 9:30 p.m., prompting participants to complete a short questionnaire. A stratified random beeping schedule was used in which the day was divided into 10 equal time intervals, and one questionnaire was scheduled at a random time in each time interval.

Session 2. Session 2 was typically scheduled 8 days after Session 1, after the completion of the ESM week. Participants handed in the research dedicated phone. Next, they completed the borderline personality disorder part of the Structured Clinical Interview for *DSM-IV* Axis II (SCID-II), in addition to a collection of self-report trait questionnaires and a computer task that were not used for the current study. Last, compliance to the ESM protocol was checked, which was used to determine the monetary compensation for their participation: participants received 35 euros when they completed at least 75% of all ESM questionnaires. For every 10% below 75% compliance, 5 euros were deducted.

Six-Month Follow-up. Six months after completing Session 2, participants received an e-mail with the invitation to complete a collection of self-report trait questionnaires that could be accessed using a hyperlink provided in the e-mail. Participants received 5 euros for the completion of this follow-up questionnaire. Data from the follow-up moment were not used in the current study.

MEASURES

Diagnostic Interviews. All participants completed a Dutch translations of the Structured Clinical Interview for *DSM-IV* Axis I Disorders (SCID-I; Van Groenestijn et al., 1999) and the borderline subscale of the Structured Clinical Interview for *DSM-IV* Axis II Personality Disorders (SCID-II; Weertman et al., 2000), which have been shown to be reliable measures of psychopathology (Lobbestael, Leurgans, & Arntz, 2011). All interviews were conducted by the first or third author of this article, who are both PhD-level psychologists trained in the use of SCID-I and SCID-II. A random selection of seven interviews were audiotaped, with explicit consent by participants, and were scored by both raters. Excellent interrater reliability was obtained

(kappa = .93 on diagnostic level, and kappa = .92 on individual symptom level).

Assessment of DSM-IV Personality Disorders (ADP-IV)-Borderline Personality Disorder Scale. The borderline personality disorder subscale of the ADP-IV is a Dutch self-report scale consisting of 10 trait items that assess each of the nine *DSM-IV-TR* diagnostic criteria for BPD (which are unchanged in *DSM-5*; Schotte et al., 1998). Each trait item is scored on a seven-point scale to indicate to what degree the trait applies to oneself, and on a three-point scale to indicate the level of distress resulting from each trait. A dimensional severity score is obtained by summing the scores on all trait items, and ranges between 7 and 70. A categorical score can be obtained by also taking the distress ratings into account. Internal consistency was good in our sample ($\alpha = 0.94$). Previous studies have demonstrated the ADP-IV-Borderline Scale to be a valid measure of BPD symptomatology (Schotte et al., 2004).

Depression Anxiety Stress Scales (DASS-21)-Depression Subscale. The Depression Anxiety Stress Scales questionnaire is a 21-item self-report measure that captures features of depression, anxiety and tension-stress. Each subscale consists of 7 items that are scored on a scale of 0 (*never*) to 3 (*most of the time*), indicating the frequency of specific cognitions and behaviors. In this study, only the depression subscale was used as a measure of depression severity. The internal consistency of the subscale was good ($\alpha = 0.96$), and this subscale was shown to be a valid measure of depression symptomatology (Antony et al., 1998; Lovibond & Lovibond, 1995).

ESM Questionnaire. Compliance with the ESM protocol was very good. Persons with BPD completed 84% (*SD* = 12), the clinical control group completed 85% (*SD* = 12), and the healthy control group completed 92% (*SD* = 7) of all scheduled ESM questionnaires (i.e., "beeps"). At each beep, participants rated the intensity and presence of different momentary states and behaviors including their emotional states. To assess momentary emotional states, participants rated how stressed, depressed, anxious, angry and restless they felt at each beep, ranging from 0 (*not at all*) to 100 (*very much*). These items were averaged to create a composite Negative Affect (NA) scale. Participants also rated how happy and relaxed they felt from 0 (*not at all*) to 100 (*very much*), which was averaged to compose a positive affect (PA) scale. These items for PA and NA were chosen to obtain a balance between high and low arousal emotion items. Reliability for PA[1] (.55 on the item level, and .98 on the person level) and NA (.59 on the item level, and .99 on the person level) was sufficient to good, following methods proposed by Nezlek (2017).

Next, a momentary valence variable was also calculated by subtracting momentary NA from momentary PA. This variable ranged from –100 (*very*

1. In the original study, "euphoric" was also assessed as a positive emotion item. However, additionally including this item resulted in lower reliability (.31 on the item level, and .98 on the person level).

negative) to 100 (*very positive*), indicating how pleasant the overall emotional state was at each beep. For states in which the intensity of PA was higher than the intensity of NA, a positive score was obtained, indicating overall positive valence or pleasantness of the current emotional state. For states in which NA was more intense than PA, a negative valence score was obtained, indicating negative valence or unpleasantness of the current emotional state.

STATISTICAL ANALYSES

Two different types of measures of emotional instability were calculated for each person. First, for PA and NA separately and for each person separately, the square root of the MSSD (RMSSD) was calculated across the entire study. Overnight lags were not taken into account. These measures reflect the magnitude of consecutive changes in positive or in negative emotional states and are the most commonly used measure of emotional instability (Houben et al., 2015). Second, the valence variable that indicates whether the current emotional state overall is pleasant (positive valence) or unpleasant (negative valence) for each person and for each moment in time was used to determine whether, compared to the previous assessment, a change had occurred from a positive/pleasant emotional state to a negative/unpleasant emotional state or vice versa. Such a change was labeled an emotional *switch* (Houben, Vansteelandt, et al., 2016). Again, overnight changes were excluded. To illustrate, a consecutive change in valence from –40 to 10 or from 15 to –30 would be labeled a switch (i.e., a switch to positive and a switch to negative, respectively), while a consecutive change from 25 to 80 or from –10 to –50 would not be considered an emotional switch but rather changes within the positive or negative emotional range. In case of a switch, the magnitude of the emotional change that resulted in such a switch was also computed, resulting in momentary switch distances from negative to positive states and switch distances from positive to negative states. Next, for each person, the average switch distance to positive emotional states and the average switch distance to negative emotional states were calculated. These capture the average magnitude of consecutive emotional change *between* positive and negative emotional states.

In addition to instability measures, the within-person standard deviation across the study period was computed for each person as a measure of variability for PA, NA, and Valence separately. Moreover, the means across the study period were calculated for each participant for PA, NA, and Valence separately.

Using these person-specific measures, we estimated a number of statistical models. First, ANOVA models and follow-up post hoc tests were used to compare groups on measures of instability. Next, ANCOVA models were estimated to compare groups on measures of instability, while taking the effect of average emotionality and emotional variability into account. For RMSSD of PA or NA, mean and within-person standard deviation of PA or NA were used. For switch distance in both directions, average valence and within-person standard deviation of valence were used. Covariates were

entered grand-mean centered. Last, we repeated these ANCOVA models, also correcting for gender and age.

RESULTS

DESCRIPTIVE STATISTICS

First, Pearson correlations between all variables of interest are reported in Table 2. As can be seen, within-person standard deviation and both types of instability indices are all significantly related. Especially for NA, average affect, within-person standard deviation, and the RMSSD are closely related. Mean PA and mean valence are closely linked to each other and to switch distances, but not significantly to within-person standard deviation of the same variables.

Differences between groups on average emotionality (i.e., mean affect) and variability (i.e., within-person standard deviation) were explored using an ANOVA. Diagnostic status had a significant effect on mean PA, mean NA, mean Valence, $F(2, 115) = 32.58$, partial eta squared = .36; $F(2, 115) = 64.59$, partial eta squared = .53; $F(2, 115) = 68.76$, partial eta squared = .55; all ps < .001, respectively; and SD of PA, SD and NA, and SD of Valence, $F(2, 115 = 6.10$, partial eta squared = .10, $p = .003$; $F(2, 115) = 37.64$, partial eta squared = .40, $p < .001$; $F(2, 115) = 15.04$, partial eta squared = .21, $p < .001$, respectively. Differences between groups are visualized in Figure 2. Both clinical groups experienced significantly higher levels of NA, lower levels of PA, and emotional states characterized by more negative valence than healthy controls. In addition, the BPD group reported more variability in PA and in the valence dimension of their emotional states than persons with MDE and healthy controls. Moreover, persons with BPD reported more variability in their NA than persons with an MDE and healthy controls, and persons with an MDE reported more variability in NA than healthy controls. In sum, although clinical groups were similar regarding their average emotionality, specificity was found regarding the degree of emotional variability.

GROUP DIFFERENCES ON MEASURES OF INSTABILITY

ANOVA models comparing groups on measures of instability showed that diagnostic status was a significant predictor of the RMSSD of PA, $F(2, 115) = 4.83$, partial eta squared = .08, $p = .010$; of RMSSD of NA, $F(2, 115) = 34$, partial eta squared = .37, $p < .001$; switch distance to positive emotional states, $F(2, 94) = 3.53$, partial eta squared = .07, $p = .033$; and switch distance to negative emotional states, $F(2, 96) = 5.40$, partial eta squared = .10, $p = .006$. To determine which groups differed on each of these measures, pairwise comparisons with Bonferroni correction for multiple testing were done. Results are visualized in Figure 3A. Without correcting for the effect of mean affect and within-person standard deviation, persons with BPD showed stronger consecutive changes in PA (measured with an RMSSD) and larger switches from positive to negative emotional states than persons with a current MDE. No differences with healthy controls were found. All three groups differed in the magnitude of consecutive changes in NA (measured with an RMSSD),

TABLE 2. Bivariate Pearson Correlations Between All Study Variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. BPD features	1											
2. Depressive symptoms	.62**	1										
3. PA mean	−.42**	−.70**	1									
4. NA mean	.54**	.76**	−.65**	1								
5. Valence mean	−.54**	−.81**	.88**	−.93**	1							
6. PA *SD*	.25**	−.04	.17	−.11	.15	1						
7. NA *SD*	.64**	.41**	−.29**	.47**	−.43**	.58**	1					
8. Valence *SD*	.47**	.17	−.02	.17	−.12	.89**	.87**	1				
9. RMSSD PA	.19*	−.06	.14	−.10	.13	.88**	.48**	.75**	1			
10. RMSSD NA	.62**	.39**	−.28**	.43**	−.40**	.51**	.91**	.76**	.55**	1		
11. Switch distance to positive	.01	−.21*	.38**	−.15	.29**	.61**	.44**	.62**	.69**	.48**	1	
12. Switch distance to negative	.17	−.13	.33**	−.07	.20*	.65**	.52**	.67**	.68**	.59**	.76**	1

Note. PA = positive affect; NA = negative affect; *SD* = within-person standard deviation; RMSSD = root mean square of successive differences. *$p < .05$. **$p < .01$ (2-tailed).

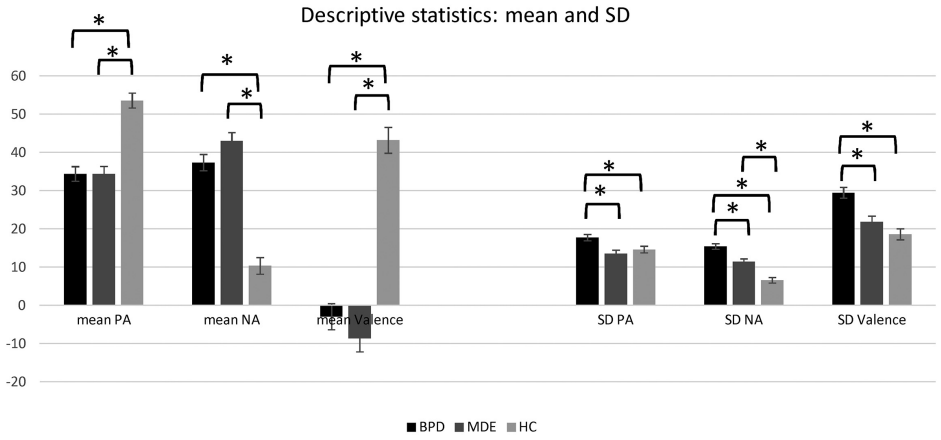


FIGURE 2. Bar graphs showing the average emotionality and average within-person standard deviation in each group, and significant differences between groups. PA = positive affect; NA = negative affect; *SD* = within-person standard deviation.

with the BPD group showing the largest changes in NA, followed by persons with an MDE, and then followed by the healthy controls, who showed the smallest changes. Last, both the BPD group and the healthy controls showed larger changes from negative to positive emotional states than persons with an MDE, but the difference between BPD and MDE was not significant after correction for multiple testing. After also correcting for age and gender, conclusions were identical with the exception that the difference between the BPD group and the MDE group on RMSSD of PA became weaker. Still gender and age were never significant covariates in any of the models.

GROUP DIFFERENCES ON MEASURES OF INSTABILITY WITH CORRECTION FOR AVERAGE EMOTIONALITY

ANCOVA models were estimated to compare groups on measures of instability, while correcting for mean affect. Diagnostic status was a significant predictor of the RMSSD of PA, $F(2, 114) = 6.29$, partial eta squared = .10, $p = .003$ after correcting for the effect of mean PA, $F(1, 114) = 5.17$, partial eta squared = .04, $p = .025$; of the RMSSD of NA, $F(2, 114) = 19.09$, partial eta squared = .25, $p < .001$ after correcting for the effect of mean NA, $F(1, 114) = 3.16$, partial eta squared = .03, $p = .078$; and of the switch distance to negative states, $F(2, 95) = 5.73$, partial eta squared = .11, $p = .004$ after correcting for the effect of mean valence, $F(1, 95) = 4.79$, partial eta squared = .05, $p = .031$. Diagnostic status was not a significant predictor of the switch distance from negative to positive emotional state anymore, $F(2, 93) = 1.37$, partial eta squared = .03, $p = .261$ after correcting for the effect of mean valence, $F(1, 93) = 4.26$, partial eta squared = .04, $p = .042$.

Pairwise comparisons with correction for multiple testing (see Figure 3B) next revealed that, taking average emotionality into account, persons with BPD exhibit larger consecutive changes in the intensity of PA and NA (measured with RMSSD) and larger changes from positive to negative states, compared to persons with an MDE and healthy controls. When age and gender were also corrected for, results were largely the same with some exceptions. For the RMSSD of PA, the difference between persons with BPD (M = 20.06, SE = .99) and MDE (M = 17.20, SE = 1.23) became smaller. Similarly, for the switch distance to negative states, the difference between persons with BPD (M = 47.73, SE = 3.17) and HC (M = 34.58, SE = 4.62) became slightly smaller. Although gender and age were never significant covariates in any of the models, their addition increased the complexity of the statistical models, which may explain these changes.

GROUP DIFFERENCES ON MEASURES OF INSTABILITY WITH CORRECTION FOR AVERAGE EMOTIONALITY AND WITHIN-PERSON STANDARD DEVIATION

Last, we repeated previous ANCOVA models, this time also including the within-person standard deviation of repeated affect assessments as a covariate in the model. Diagnostic status was not a significant predictor of the RMSSD of PA anymore, $F(2, 113) = 1.30$, partial eta squared = .02, $p = .276$, after correcting for the effect of mean PA, $F(1, 113) = 1.29$, partial eta squared = .01, $p = .259$, and the within-person standard deviation of PA, $F(1, 113) = 340.60$, partial eta squared = .75, $p < .001$. Nor was diagnostic status a significant predictor of the RMSSD of NA, $F(2, 113) = 1.39$, partial eta squared = .02, $p < .254$, after correcting for the effect of mean NA, $F(1, 113) = 0.01$, partial eta squared = 0, $p = .907$, and the effect of the within-person standard deviation of NA, $F(1, 113) = 292.81$, partial eta squared = .72, $p < .001$. Similarly, diagnostic status was not a significant predictor of the switch distance from negative to positive emotional state, $F(2, 92) = 2.93$, partial eta squared = .06, $p = .058$, after correcting for the effect of mean valence, $F(1, 92) = 1.96$, partial eta squared = .02, $p = .165$, and the effect of the within-person standard deviation of valence, $F(1, 92) = 73.53$, partial eta squared = .44, $p < .001$, or of the switch distance to negative states, $F(2, 94) = 1.59$, partial eta squared = .03, $p = .209$, after correcting for the effect of mean valence, $F(1, 94) = 0.97$, partial eta squared = .01, $p = .326$, and the effect of the within-person standard deviation of valence, $F(1, 94) = 70.51$, partial eta squared = .43, $p < .001$. Results were identical when we also corrected for age and gender, with one notable difference. Diagnostic status had a significant effect on switch distance to positive states, $F(2, 90) = 3.08$, partial eta squared = .06, $p = .051$, after accounting for the effect of mean valence, $F(1, 90) = 2.18$, partial eta squared = .02, $p = .143$, the within-person standard deviation of valence, $F(1, 90) = 68.55$, partial eta squared = .43, $p < .001$, gender, $F(1, 90) = 1.94$, partial eta squared = .02, $p = .167$, and age, $F(1, 90) = 0.75$, partial eta squared = .01, $p = .389$. More specifically, persons with BPD had a significantly ($p = .016$) smaller switch distance to positive (M = 34.25, SE = 3.80) than healthy controls (M = 45.92, SE = 4.65).

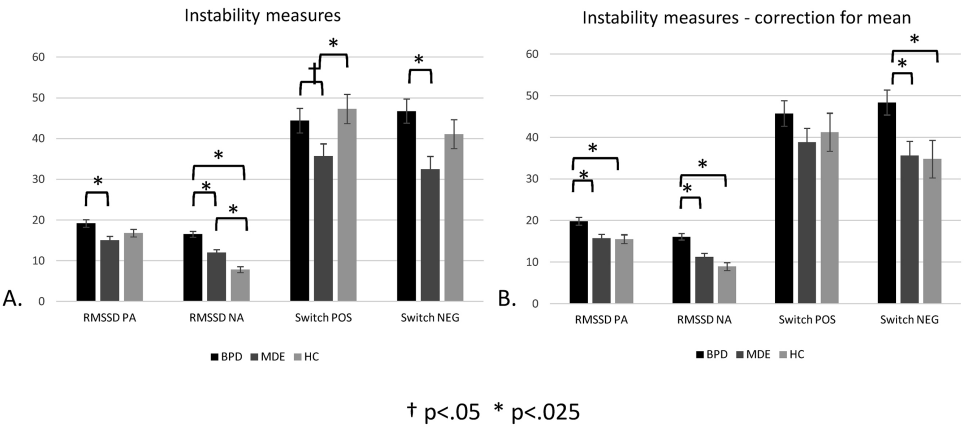


FIGURE 3. Bar graphs showing the instability measures for each group and significant differences between groups, both without (A) and with (B) correction for average emotionality. PA = positive affect; NA = negative affect; RMSSD = root mean square of successive differences.

DISCUSSION

In this study, we thoroughly scrutinized the statistical specificity of relationship between emotional instability and BPD in daily life. We examined the statistical specificity of this relationship by correcting for statistical overlap between instability indices on the one hand and average levels and within-person standard deviation of the same variables on the other hand. This was done because instability measures consist of different components (i.e., emotional variability, and a temporal dependency aspect) and research has indicated that the relationship between emotional instability and psychological well-being could be confounded by average levels and the within-person standard deviation of emotional states over time. Therefore, we wanted to evaluate whether the relation between BPD and instability was not simply driven by the association between BPD and emotional variability (as measured with within-person standard deviations). This would shed light on the exact pattern of emotion dynamics that is characteristic of BPD. Moreover, the transdiagnostic nature of our findings were evaluated by comparing a BPD sample to both a clinical group and a healthy control group. In order to answer these questions, we ran an ESM study. Participants rated their current emotional states 10 times a day for 7 consecutive days throughout their everyday lives. Using these repeated assessments, we extracted and examined four different instability measures in this study: the RMSSD of PA and the RMSSD of NA, which focus on quantitative changes in PA *or* NA, and switch distances from positive to negative and from negative to positive emotional states, which also take the quality of changes *between* positive and negative emotional states into account.

Results indicated that, without correction for average emotionality and within-person standard deviation, transdiagnostic specificity was found for the RMSSD of NA, showing that persons with BPD experienced larger consecutive changes in NA than both clinical and healthy controls did. Next, persons with BPD also exhibited stronger consecutive changes in PA and larger switches from positive to negative emotional states than persons with a current MDE, but no differences with healthy controls were found. This indicates that persons with BPD exhibit heightened instability in comparison to persons with an MDE, but to an extent are still comparable to healthy controls, suggesting that persons with an MDE show blunted emotional responsiveness instead. When next correcting for differences between groups in average emotionality, clearer patterns of transdiagnostic specificity were found: Persons with BPD showed larger consecutive changes in the intensity of PA, larger consecutive changes in NA, and larger changes from positive to negative states compared to both persons with an MDE and healthy controls. In a last step, when correcting for both average emotionality and within-person standard deviation or variability in affect, we found no differences between groups in emotional instability indices.

When we examined differences between groups in terms of instability without correcting for emotional variability (i.e., within-person standard deviation), our findings are in line with a large body of research showing that BPD is linked to heightened emotional instability (e.g., Ebner-Priemer et al., 2007; Houben et al., 2015; Houben, Vansteelandt, et al., 2016; Santangelo et al., 2014; Snir, Bar-Kalifa, Berenson, Downey, & Rafaeli, 2017; Trull et al., 2008). Our findings also disclosed transdiagnostic specificity, showing that emotional instability was higher in a BPD group compared to both a healthy group and a clinical control group. When we corrected for differences between groups in terms of average emotionality, the differences between groups were more pronounced. These findings add to the discussion of whether the patterns of change observed in daily life of persons with BPD are specific to BPD or rather reflect a transdiagnostic feature. Indeed, some studies have shown that persons with BPD are characterized by stronger emotional instability, compared to persons with other psychopathological complaints. For instance, Trull et al. (2008) showed that persons with BPD experience stronger consecutive changes in emotional intensity than persons with a major depressive disorder, but only for hostility, fear, and sadness, and not for overall positive affect or negative affect. Similarly, Snir et al. (2017) concluded that persons with BPD show larger consecutive emotional changes in their negative affect than persons with an avoidant personality disorder. In contrast, other studies have concluded that no specificity can be observed regarding patterns of emotional instability. Mneimne, Fleeson, Arnold, and Furr (2018) concluded that stronger emotional instability in anger and irritability was largely transdiagnostic when comparing persons with BPD to persons with a major depressive disorder or bipolar disorder. Similarly, no differences were found between persons with BPD, persons with posttraumatic stress disorder, and persons with bulimia nervosa (Santangelo et al., 2014) regarding the magnitude of the consecutive changes in emotional valence and momentary distress, and regarding the magnitude of changes between positive and negative emotional states (Houben,

Bohus, et al., 2016). Again, no differences were found between persons with BPD and persons with major depressive disorder regarding the magnitude of consecutive emotional changes between positive and negative states over time (Houben, Bohus, et al., 2016).

When comparing emotional instability between groups, after correcting for differences in groups in terms of emotional variability (i.e., within-person standard deviation), no differences were found anymore. This indicates that the differences between groups in emotional instability can be explained by differences in variability. Research by Jahng et al. (2008) has indicated that the MSSD, as a measure of emotional instability can be expressed in terms of (a) a within-person variance, capturing the amplitude of emotional responses or the degree of deviations around the average emotional level, and thus emotional variability; and (b) the inverse of an autocorrelation, which reflects the temporal aspect of these changes. Our findings now illustrate that if we keep the variability component constant, that the component that remains (i.e., the temporal dependency component) does not seem to differ between groups anymore. In other words, what truly differs between persons with BPD on the one hand and the clinical and healthy control groups on the other hand is the degree of emotional variability or deviations around the average emotional levels in terms of PA, NA, and the overall valence of the emotional states. More specifically, persons with BPD experience more extreme emotional deviations from how pleasant or unpleasant they usually or typically feel. This drives findings that persons with BPD exhibit heightened emotional instability, but this instability does not parsimoniously capture the emotion dynamics that are characteristic of persons with BPD. In fact, the temporal order of the changes seems to be less crucial to differentiate persons with BPD from clinical and healthy controls.

These findings are in line with the studies by Ebner-Priemer et al. (2015) and Santangelo et al. (2016) showing that persons with BPD have a more negative and aroused emotional baseline and exhibit stronger deviations from this baseline. Less clear indications were found for differences in attractor strength, which is a parameter of emotional change that is related to the temporal dependency of changes. Moreover, a study by Houben and Kuppens (2020) indicated that BPD features were consistently and specifically linked to larger variability in negative affect and not to inertia of negative affect, which is again in line with the finding that variability around the baseline, but not the temporal dependency of these changes, is crucial to characterize the emotional trajectory of persons with BPD.

Our findings are also compatible with important theoretical models of BPD highlighting the prominence of affective dysregulation in BPD. Linehan's biosocial theory (Linehan et al., 2007) states that persons with BPD are characterized by an increased vulnerability to high emotionality, which is defined by heightened sensitivity to emotional stimuli, intense reactivity to such stimuli, and a slow return to emotional baseline. The finding that persons with BPD are characterized by high average levels of NA and low levels of PA is in line with the idea that they have a heightened sensitivity to especially negative emotional stimuli, and thus are more likely to experience negative emotions (Carpenter & Trull, 2013; Linehan et al., 2007). Next, the finding

that persons with BPD show strong deviations from their average emotional baseline, rather than large, abrupt changes from one time point to the next, is in line with the idea of strong emotional reactivity to emotional stimuli combined with a slow emotional recovery (Linehan et al., 2007). Indeed, this would result in the occurrence of emotional peaks with a high amplitude that shows a very slow and gradual decay. In contrast, strong emotional instability consisting of large, abrupt emotional changes that follow a strong cyclical pattern would be expected as a result of high reactivity to stimuli combined with a steep (and almost complete) recovery, which is again followed by a new emotional response.

Although the focus on overall patterns of emotional change can provide some insight into the emotional functioning of persons, an important next goal in this research field is to further examine the exact mechanisms that result in these patterns. Such information can provide more fine-grained information about which processes of healthy emotional functioning are compromised and thus should be tackled during treatment. This is in line with the treatment approach of dialectical behavioral therapy, in which an important part focuses on distress tolerance and emotion regulation skills (Linehan et al., 2007). The finding that persons with BPD show heightened emotional variability is in line with the components of emotion vulnerability proposed by Linehan (Linehan et al., 2007), but further studies should explore the exact mechanism underlying these emotional changes. Speculatively, this extreme emotional responding in BPD could be the result of very strong and acute reactivity to specific emotional triggers in daily life. Next, the lack of effective emotion regulation combined with the possibility of fast reactivation of the emotional response due to the occurrence of new emotional triggers can explain the slow decay of the emotional response. These processes would result in high within-person standard deviation of affective states (i.e., larger variability around and deviations from the emotional baseline), yet not follow a pattern characterized by abrupt consecutive emotional changes.

Some limitations should be noted. First, our clinical control group consisted of persons with a current major depressive episode, but without a diagnosis of BPD. More clinical groups should be explored in the future to better understand the true specific nature of emotion dynamic patterns in daily life. Second, most clinical participants were taking psychotropic medication during the completion of the study. Such medication is expected to have an impact on emotional experiences and the variability thereof. Unfortunately, because most participants took a large variety of different types of medication, it is very difficult to account for it in a systematic way. However, because similar medication use is reported in both the MDE and the BPD groups, it is unlikely that group differences in patterns of emotional change are driven solely by medication use. Third, while our BPD sample consisted of persons who scored very high on BPD symptomatology, the MDE sample was mostly moderately depressed. The most severely depressed patients often refused to participate in this study because the intensive nature of the study requires participants to have sufficient energy and concentration to repeatedly complete questionnaires throughout everyday life. This could have resulted in a selection bias. However, such patients likely exhibit more extremely blunted patterns of

emotional change, which would likely result in even larger group differences in patterns of emotional change. Last, there were no clear indications that the repeated emotional assessments in the study had a positive or negative effect on the emotional states of the participants over time, for example, by improving emotional insight or by inducing annoyance. More explicit attention should be given to positive or negative reactivity effects in ESM studies, especially for persons with BPD who suffer from emotional disturbances and strong emotional reactivity.

To conclude, the goal was to examine which pattern of emotion dynamics parsimoniously captures the daily life emotional trajectories of persons with BPD. Previous studies have highlighted the importance of emotional instability in BPD, suggesting that persons with BPD exhibit emotional changes that occur abruptly from one moment to the next, following a cyclical pattern. However, our findings show that if we disentangle the different components of emotional instability, that what truly differs between persons with BPD on the one hand and healthy and clinical control groups on the other hand is the presence of heightened emotional variability or extreme emotional deviations from how persons usually feel. The temporal order of the changes is not crucial to differentiate between the groups.

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