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Intensified emotion perception in depression: differences in physiological arousal and subjective perceptions

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Abstract

People suffering from depression perceive themselves and their surroundings as more negative than healthy ones. An explanation might be that depressed individuals experience negative information as more stressful than non-depressed subjects and, consequently, respond in an amplified manner on a subjective and physiological level. To test this proposition, we presented 41 patients with recurrent depressive episodes and 42 controls with stimuli from the International Affective Picture System split into three valence categories while different parameters of physiological arousal (e.g., heart rate variability) and subjective perceptions of valence and arousal were assessed. Furthermore, we examined social skills and emotional competence. Results regarding physiological arousal revealed an elevated skin temperature and a more accentuated respiratory frequency in depressed subjects. Furthermore, depressed subjects rated the stimuli as more negative and arousing, which was associated with reduced social and emotional competence. Variation in antidepressant medication, menstrual cycle and other factors that have an impact on HRV are a potential bias. Our findings suggest an intensified perception of negative emotion in depressed individuals as compared to controls that manifests itself in an

increased physiological arousal on a subjective level. This intensified emotion perception is further associated with deficits in social and emotional competence.

Key words: depression, physiology, emotion, autonomic nervous system (ANS), heart rate variability (HRV), International Affective Picture System, social skills

1 Introduction

Major depressive disorder (MDD) is defined as a condition that includes key symptoms such as depressed mood and loss of interest or pleasure in daily activities as well as at least four others (e.g., changes in appetite or sleep) over a period of two weeks or longer (American Psychiatric Association, 2013). However, it is not fully understood, yet, which underlying mechanisms lead to these symptoms. Multifactorial models of mental disorders emphasize the importance of the way we deal with stress as one vital factor that determines psychological health or sickness (Nemeroff and Vale, 2005). Since depressed individuals have been shown to exhibit a *negativity bias* (Bourke et al., 2010; Gollan et al., 2016), i.e., to selectively emphasize and better remember negative information (Ridout et al., 2003; Watkins et al., 1996) one could assume that this bias leads them to perceive negative information as more stressful and respond to it in an amplified manner as compared to non-depressed individuals. Such an intensified reaction might consequently lead to an elevated stress level in depressed individuals.

Stress can be defined as a stimulus that disrupts the physiological or psychological homeostasis of an individual when encountering internal or external harmful events (Kyrou and Tsigos, 2009). On a biological level the autonomic nervous system (ANS) is responsible for an organism's stress response. The heart rate and skin conductance, for instance, will react within a range of one to three seconds (Braithwaite et al., 2013; Guerra et al., 2012). The ANS regulates visceral functions through its sympathetic and parasympathetic arms which act antagonistically to preserve a dynamic equilibrium of vital functions (Xhyheri et al., 2012). For example, the sympathetic arm can induce excitation by increasing heart rate and blood pressure within seconds (Ulrich-Lai and Herman, 2009). A dysregulation of ANS activity impairs a person's ability to cope with stress and might, thus, be an important factor in the development and perpetuation of MDD. In fact, MDD has been repeatedly linked to altered patterns of ANS functioning (Bassett, 2015; Branković, 2008; Brunoni et al., 2013).

There are various signals that reflect ANS activity. Heart rate variability (HRV), among others, describes fluctuations between intervals of consecutive heartbeats as a result of ANS dynamics on cardiovascular control that maintain the dynamic equilibrium of vital functions (Xhyheri et al., 2012). Reductions in HRV have not only been found in MDD but in various psychiatric disorders such as schizophrenia (Moon et al., 2013), bipolar disorder (Bassett, 2015; Bassett et al., 2016; Henry et al., 2010) or post-traumatic stress disorder

(Moon et al., 2013). Kemp and colleagues (2010) conducted a meta-analysis examining HRV in 18 samples of altogether 673 patients suffering from MDD and 407 healthy controls. He found that MDD subjects showed a reduced HRV in time domain measures and lower HF power. A literature review of Stapelberg and colleagues (2012) came to a similar conclusion. Further evidence was added by Wang and others (2013) who found reduced SDNN, SDANN, RMSSD, pNN50 and HF power in depressed patients as well as by Ha and colleagues (2015) who found lower SDNN, RMSSD and pNN50 in first-episode depressed female subjects. However, according to Kemp and others (2014a), heterogeneous samples and confounding variables might contort results. For example, he found lower RMSSD levels in subjects suffering from melancholia than in a nonmelancholic sample (Kemp et al., 2014b) and reduced RMSSD and HF values in depressed subjects with comorbid generalized anxiety as compared to MDD subjects without comorbid anxiety (Kemp et al., 2012). On the other hand, Bassett and others (2016) reported reduced SDNN scores in a sample of patients suffering from recurrent depressive disorder in remission. Antidepressant medication is considered another confounding variable since it has been reported to reduce HRV. While the exact influences of antidepressant medication are not completely understood, yet, it appears that tricyclic substances influence HRV the most (Kemp et al., 2010; Udupa et al., 2011) whereas, e.g., selective serotonin reuptake inhibitors (SSRIs) seem to have less impact or no impact at all (Kemp et al., 2010; van Zyl et al., 2008)."

Furthermore, the human stress response includes shifts in the skin conductance level, the galvanic skin response (GSR). Research concerning GSR at rest reveals a heterogeneous picture. Some publications suggest reduced GSR levels as a biomarker of depression (Storrie et al., 1981; Straub et al., 1992; Ward et al., 1983). However, others found increases (Branković, 2008; Toone et al., 1981).

While baseline levels of HRV and GSR in depression have been examined by a number of research groups, few studies have assessed how those signals change in response to negative, emotionally arousing stimuli. Shinba (2014) found that HF power and the LF/HF-ratio of HRV was increased in depressed subjects as compared to a control sample while performing a cognitive challenge task. However, Shinba's sample was quite small (*N*=22 depressed subjects). Schneider and colleagues (2012) reported elevated levels of GSR in MDD during the presentation of short video clips depicting actors expressing emotions by face, voice and prosody. Gehricke and Shapiro (2001), however, did not find

changes in GSR while imagining sad and happy situations. Finally, Lin and others (2011) measured GSR, heart rate, RSP and TEMP and their association to depressive symptoms during an arithmetic stress test. They found no variations in GSR but noted a correlation between TEMP and depressive symptoms. Yet, they did not use emotionally stressful material and merely measured depressive symptoms in a healthy student sample using the Beck Depression Inventory II (BDI-II; Hautzinger et al., 2009).

Prior research does not give a comprehensive picture of how depressed subjects react to emotional stress. Studies differ largely in their choice of stress induction paradigm oftentimes using stimuli that have not been validated according to their arousal or valence. Most researchers focus on one indicator of ANS activity only. Respiratory frequency (i.e., breaths per minute; RSP) and skin temperature (TEMP) as measures of ANS activity have - to our knowledge - received very little attention in research on depression so far. Also, we note differences in the diagnostic inclusion criteria for the depressed subjects. Furthermore, various symptoms associated with MDD were not assessed in prior studies. For example, depressed individuals are often limited in their ability to master social situations (Quintana et al., 2012). Consequently, they exhibit symptoms such as social withdrawal, which restrict them in their social relationships. Those deficits in social skills might be caused by poor ANS regulation (e.g., reduced ANS) according to Quintana and colleagues (2012) and the *polyvagal theory* (Cole and Milstead, 1989; Cole et al., 1987).

Thus, the aim of the current study was to provide a comprehensive overview of how depressed individuals perceive negative information on a biological as well as behavioral level as compared to healthy control subjects. We focused on assessing four different markers of ANS activity. Moreover, we used stimuli that are well validated and were proven to elicit negative emotions. We included only depressed patients that were diagnosed by a trained clinician and were currently experiencing an acute depressive episode into our sample. We hypothesized that depressed subjects would not only perceive the negative information as more intense but would also show higher levels of arousal indicated by increased ANS activity (RSP, TEMP, GSR) as compared to healthy control subjects and that HRV will be reduced. Furthermore, we expected that these differences in physiological arousal would be associated with symptoms of depression, such as reduced emotional and social competence.

2 Methods and Material

2.1 Participants

41 patients diagnosed with recurrent depressive disorder (25 females, 16 males; M_{age}=43.85 years, *SD*=12.18) and 42 healthy controls (29 females, 13 males; M_{age}=40.67 years, *SD*=14.28) were included in the study. Patients were recruited as inpatients of the Department of Psychiatry, Psychosomatic Medicine and Psychotherapy of the University Hospital of Frankfurt/Main, Germany or via announcements in newspapers. In order to confirm the diagnosis in the patient group and to rule out any mental illness in the control group we conducted the Structured Clinical Interview for DSM-IV (SCID-I and SCID-II; German version by Wittchen et al., 1997).

Patients had suffered from depressive episodes for up to 43 years (*M*=12.75, *SD*=31.11) and were currently experiencing a depressive episode as diagnosed by a treating clinician, based on DSM-V criteria. Patients suffering from comorbid axis I or II disorders were excluded from the study with the exception of anxiety disorders. Depressive symptom severity assessed using the BDI II (retest-reliability: *r*=0.78-0.93; construct validity: α=0.92-0.93) was moderate to severe (*M*=22.66; *SD*=10.60). Thirty-three patients were currently taking antidepressant medication. Medication substance and dose had been stable for at least two weeks prior to testing. To compare different medication doses, scores equivalent to antidepressant and antipsychotic medication were calculated (Bollini et al., 1999; Woods, 2003).

Control subjects had no current drug-abuse, addiction or neurological illness. In order to assure comparable visual attention abilities we applied the Trail Making Test A (TMT-A; Nuechterlein and Green, 2006). Since they were shown to affect HRV (Xhyheri et al., 2012), the body mass index (BMI; kg/m^2) and nicotine consumption (cigarettes/day) were assessed as control variables (see Table 1). All participants received a description of the experiment and gave written informed consent before participating. The ethical board of the Medical School of the University Hospital of the Goethe-University, Frankfurt/Main, Germany, approved experimental procedures.

2.2 Assessment of indicators of ANS activity

We used the "NeXus-10 MKII"-system and the software Biotrace+ to record and analyze the function of the ANS (HRV, GSR, TEMP, RSP). In order to have a stationary and representative baseline HRV sample, a resting period of 2-5 min. time preceded the

baseline measurement. A stationary 4-min time period from the middle of the baseline was then selected for HRV analysis since four-minutes are an acceptable time frame for short-term measurements (Task Force, 1996; Xhyheri et al., 2012).

In order to assess HRV, lead II electrocardiogram (ECG) was measured at 2048 Hz. Time intervals between successive heart beats needed for HRV analyses were extracted from the ECG using the QRS detector of Kubios HRV software (Tarvainen et al., 2014). Every recording was visually checked for possible artifacts or ectopic beats, and corrected using the artifact correction tool of Kubios HRV if necessary. Very low frequency trend components (frequencies below 0.04 Hz) were filtered out from HRV time series using the smoothness priors method (Tarvainen et al., 2002). All HRV computations were performed using the Kubios HRV software. Time domain measures included the mean normal-to-normal interval (NN), the standard deviation of the NN interval (SDNN) and the square root of the mean, squared differences of successive NN intervals (RMSSD) as well as poincaré plots (SD 1 and 2). As a frequency domain measure, we included high frequency (HF; 0.15 to 0.5 Hz) power. For estimating HF power, the RR interval time series were first interpolated using a 4 Hz cubic spline to have equidistantly sampled data and the power spectrum estimate was then computed based on an autoregressive (AR) model (model order=16) fitted into the interpolated data. The AR spectrum estimate was selected because its frequency resolution is theoretically better compared to discrete Fourier transform, especially when analyzing short time periods as was the case here.

The GSR signal was measured in µS using two Ag-AgCL electrodes that were secured to the intermediate phalanges of digits II and IV of the left hand. In order to measure TEMP, a small tip sensor was attached to the distal phalange of digit III in the left hand. Finally, breaths per minute were measured using a respiration sensor fastened around the subjects' chest above the navel. The raw signal from the RSP sensor (in mVolts) had an offset of 1500 and was amplified by -1 to make sure the values would go up when breathing in, and down when breathing out. The recorded samples were then analyzed using a peak detection algorithm that detects breaths regardless if the peaks are high or low. All data were manually screened for artifacts looking for sudden spikes, rapid oscillations or signals that were out of the normal healthy range (e.g., GSR > 20µS or TEMP > 39°C). In cases of more than 5% artifacts, we excluded the data from further analysis.

2.3 Emotion Perception Paradigm

The International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) was used to evoke an emotional reaction in the participants. The IAPS provides normative ratings of valence and arousal for all pictures on a scale from one to nine. In the current study, a subset of 90 pictures was taken from the IAPS battery and split equally into three categories of each 30 stimuli: *neutral* pictures (valence: *M*=5.09, *SD*=0.23 / arousal: *M*=2.99, *SD*=0.63) depicted mainly day-to-day objects like a telephone. *Unpleasant* pictures (valence: *M*=3.63, *SD*=0.13 / arousal: *M*=5.18, *SD*=0.86) showed scenarios like an attacking shark or a child crying at the dentist. Lastly, pictures such as mutilated faces or an old man sitting at the side of his dying wife's bed were classified as *very unpleasant* (valence: *M*=1.93, *SD*=0.17 / arousal: *M*=5.87, *SD*=0.65).

2.4 Experimental protocol

After the first baseline was recorded trial one of the emotion perception paradigm followed. Forty-five pictures (15 of each valence category) were presented in blocks of each five pictures of the same valence category. Thus, there were nine blocks of five pictures each presented in a randomized order (see also figure 1b). While participants were viewing the stimuli, they stayed attached to the biofeedback device so ANS indicators could be assessed. They were instructed to sit still, look at the pictures and focus on their content. After a second baseline, participants were detached from the biofeedback device and trial two followed. During this trial nine randomized blocks of each five pictures of the same valence category were presented just as in trial one. However, the participants' task was to issue valence and arousal ratings on a scale from zero to ten for each picture. For a summary of the procedure, please see Figure 1a.

2.5 Assessment of emotional competence and social skills

As a self-reported estimate of social skills, the Social Skills Inventory (SSI; Riggio and Carney, 2003) was assessed (test-retest reliability: r=0.81-0.96; internal consistency: α=0.75-0.88). We used the subscales *social expressiveness*, *sensitivity* and *control* to assess the subjects' ability to communicate, receive, interpret and control social signals. As a measure of emotional competence, the Emotional Competence Questionnaire (ECQ; Rindermann, 2009) can be divided into four subscales: *Recognition and understanding of one's own emotions*, *recognition of others' emotions*, *emotion regulation* and *emotional expressivity*. The ECQ provides high levels of internal consistency (α=.86-.93) and its validity has been confirmed through exploratory and confirmatory factor analyses.

2.6 Statistical analysis

In the emotion perception paradigm, all indicators of ANS activity were estimated within 20-second time windows (the duration of one block of pictures) and averaged over the three blocks of similar emotional conditions. We calculated the mean standard deviation (SD) and arithmetic mean (AM) for GSR, TEMP and RSP as well as HRV parameters for each of the five conditions (baseline 1, baseline 2, neutral, unpleasant and very unpleasant pictures). We then computed repeated measures analyses of covariance (ANCOVAs) including condition as a repeated measure for each ANS signal. We included age, nicotine consumption, BMI and medication equivalents as covariates in our analyses if prior correlational analyses showed significant associations with physiological variables. Subjects that were suffering from coronary heart disease, cardiac dysrhythmia, cardiac vascular defect, angiopathy, heart attack or heart failure were excluded from HRV analyses. Furthermore, we investigated group differences in the BDI II, SSI and ECQ scores using *t*-tests. Prior to our analyses we checked that assumptions for all statistical methods applied. Some of the variables were not normally distributed (e.g., estimates of HRV). However, since there is sufficient evidence that analyses of variance as well as *t*-tests are fairly robust to violations of the normality assumption (Bortz, 2010; Harwell et al., 1992; Lumley et al., 2002; Schmider et al., 2015) and since further evidence discourages from using non-parametric alternatives to the ANOVA or *t*-test (Edgington, 1995; Tanizaki, 1997; Zimmerman, 1998) we chose to use parametric statistical methods. In case of multiple comparisons, we conducted Bonferroni corrections.

3 Results

3.1 Cognitive measures and confounding variables

Control subjects did not significantly differ from the patient group in gender ($\chi^2(1)=0.60$, $p=0.440$) or age ($t(81)=0.11$, $p=0.278$). Nicotine consumption was comparable across groups ($t(80)=1.92$, $p=0.058$). However, patients revealed higher BMI scores ($t(81)=2.68$, $p=0.009$). Scores in visual attention (TMT-A) did not differ significantly ($t(74.63)=-1.92$, $p=0.580$).

3.2 Indicators of ANS activity

Due to artifacts mostly caused by technical complications with the GSR sensor, data of eight control subjects and seven patients could not be included in our analysis. Mean GSR values in the patient group were elevated but not significantly ($F(1,65)=1.76$; $p=0.189$) as was shown in a ANCOVA including age as a covariate. Also, a significant effect of the emotion condition factor was observed, i.e. an increase in GSR across emotion condition ($F(1,62)=5.29$; $p=0.001$). However, no significant interaction between time of measurement and group was observed ($F(1,62)=1.16$; $p=0.336$) pointing towards comparable increases in GSR in both groups.

A repeated measure ANCOVA with the BMI as a covariate revealed significantly higher TEMP levels in the patient group as compared to control subjects ($F(1,78)=8.29$; $p=0.005$). Post-hoc ANCOVAs revealed significant group differences in baseline 1 for the AM ($F(1,79)=8.13$; $p=0.006$) and SD ($F(1,79)=6.84$; $p=0.011$); in the neutral condition for the AM ($F(1,80)=8.62$; $p=0.004$); in the low negative condition for the AM ($F(1,80)=8.74$; $p=0.004$); and in the high negative condition for the AM ($F(1,80)=9.108$; $p=0.003$) (see Figure 2).

Regarding RSP, data of two control subjects had to be excluded from further analysis due to artifacts. An ANCOVA including the average nicotine consumption and chlorpromazine equivalents as covariates revealed no significant group difference ($F(1,77)=0.65$; $p=0.424$). Emotion condition, however, did show a significant effect ($F(1,74)=3.814$; $p=0.007$). Post-hoc dependent *t*-tests revealed that RSP levels increased from baseline 1 to neutral pictures ($t(40)=-3.56$, $p=0.001$), from neutral to unpleasant pictures ($t(40)=-3.00$, $p=0.005$) and from baseline 1 to very unpleasant pictures ($t(40)=3.33$, $p=0.002$) in the patient sample. In the control sample significant changes were only observed between neutral and unpleasant pictures ($t(41)=-2.09$, $p=0.043$).

Due to artifacts and illnesses related to the heart (s. section 2.6), five subjects (one patient and four control subjects) had to be excluded from HRV analyses. Significant group differences for the RMSSD ($F(1,75)=5.37$; $p=0.023$), the SDNN ($F(1,75)=7.00$; $p=0.010$), SD1 ($F(1,75)=5.34$; $p=0.024$) and SD2 ($F(1,75)=4.28$; $p=0.042$) pointed towards a limited HRV in the patient group. However, these differences did not reach a significant level anymore after accounting for Age and Amitryptilin equivalents (RMSSD: $F(1,73)=0.00$; $p=0.965$; SDNN: $F(1,73)=0.00$; $p=0.990$; SD1: $F(1,73)=0.00$; $p=.961$; SD2: $F(1,73)=0.58$; $p=0.448$). To have a closer look at the data, please view Figure 3. Before analyzing HF power as a frequency domain measure, respiratory rate was checked and was within the HF frequency band (0.15-0.5 Hz) in all subjects. No significant group differences were found with (HFpow: $F(1,74)=0.786$; $p=0.378$) or without including covariates (HFpow: $F(1,75)=1.90$; $p=0.172$).

3.3 Emotion Perception Paradigm

As can be seen in Figure 4 patients rated the pictures as significantly more negative ($F(1,80)=6.66$; $p=0.012$) as well as more arousing ($F(1,80)=6.76$; $p=0.011$). Post hoc *t*-tests confirmed significant group differences in the neutral condition (valence: $t(62.8)=2.90$, $p=0.005$; arousal: $t(80)=2.73$, $p=0.008$), in the unpleasant condition (arousal: $t(80)=2.54$, $p=0.034$) and in the very unpleasant condition (valence: $t(71.42)=2.24$, $p=0.029$; arousal: $t(74.79)=2.30$, $p=0.025$).

3.4 Emotional competence and social skills

According to ECQ scores, patients rated their ability to control one's own emotions as lower than the control group ($t(81)=-3.52$, $p=0.001$) while their estimates of emotional expressivity ($t(81)=2.48$, $p=0.015$) and recognition of one's own emotions were higher ($t(81)=3.58$, $p=0.001$). Social skills differed significantly between the two groups in all three subscales. While patients rated their social expressiveness (SE; $t(81)=-4.22$, $p<0.001$) and control (SC; $t(81)=-5.09$, $p<0.001$) as lower than healthy participants, they estimated their social sensitivity (SS; $t(81)=3.87$, $p<0.001$) as higher (see also Figure 5).

Multiple correlational analyses were computed in order to analyze associations between the arousal and valence ratings and the questionnaire scores in the ECQ, SSI and BDI (s. Supplemental Material, Table S1). Strong associations were found between arousal as well as valence ratings and the three subscales of the SSI. After a Bonferroni correction for multiple comparisons (adjusted $r=0.006$), 7 out of the initial 18 significant associations remained significant, mostly in the subscale *social control* (SSI-SC). Subscales of the ECQ

were also associated with valence and arousal ratings (r=0.004-0.050). After correcting for multiple comparisons (adjusted r=0.002 [ECQ]), however, none of the correlations remained significant. Finally, strong correlations between the BDI II and arousal as well as valence in all conditions were found (r=0.001-0.016).

Since measures of HRV seemed to be strongly influenced by medication, we did not compute correlations between those measures and depressive symptoms. Of the other indicators of ANS activity, TEMP correlated significantly with BDI II scores in all five conditions (r=0.003-0.008). Furthermore, significant associations were found with the scales emotional expressivity (r=0.018-0.048) and recognition of one's own emotions ($r\leq$0.000-0.001) in the ECQ for all five conditions. After correcting for multiple comparisons none of the other associations between indicators of ANS activity and self-reported depressive symptoms (SSI, ECQ, BDI II) reached a significant level.

4 Discussion

This study sheds light on one specific aspect of emotion processing - emotion perception - the actual sensation that arises consciously or unconsciously as an immediate response to an emotionally arousing stimulus. The aim of the study was to test the hypothesis of an intense perception of negative information in depressed subjects on a physiological and subjective level. We first assessed baseline measurements of different indicators of ANS activity. Then, we presented all participants with negative, arousing stimuli while measuring ANS signals as well as subjective perceptions of arousal and valence. We observed an elevated skin temperature in all conditions as well as an accentuated breathing frequency in response to the stimuli in the patient sample. Moreover, depressed subjects perceived the stimuli as more negative and arousing than healthy controls. This amplified reaction of emotion correlated with deficits in social and emotional skills, as predicted.

4.1 Differences in emotion perception between patients and control subjects

While prior studies found elevated (Branković, 2008; Toone et al., 1981) or reduced (Straub et al., 1992; Ward et al., 1983) GSR levels at rest, our results did not reveal group differences at baseline. Furthermore, while we did observe increases in GSR levels during the emotion perception paradigm, those variations did not differ between patients and controls. Hence, our results are in line with Gehricke and Shapiro (2001) as well as Lin and colleagues (2011) who did not find variations in GSR in response to stress tasks in depressed subjects as compared to healthy individuals, either. Consequently, we have to agree with Straub and colleagues (1992) who suggest that GSR levels do not appear to reliably distinguish between depressed and non-depressed individuals. Furthermore, GRS levels do not seem to serve as an indicator of emotional arousal.

Baseline levels in RSP did not differ between groups. However, we observed that with increasing negativity in the picture material, the patients' respiratory frequency rose indicative of an intensified physiological reaction to negative emotional information (see also Figure 3). Hence, RSP might be a valid indicator of emotional arousal that – to our best knowledge – has not been assessed in depressed subjects before. TEMP can be considered another ANS signal that has found little attention in research so far. In our experiment TEMP was significantly increased in the patient group. These results are in line with Lin and colleagues (2011) who found TEMP to be elevated in a depressed sample while handling an arithmetic stress task. Since TEMP levels remained stable throughout

the measurement in both groups we can assume that it does not react sensitively to emotional stress but is to be considered a marker of general differences in physiological arousal between depressed and non-depressed subjects. Regarding HRV, we find that reduced HRV scores such as the SDNN (p=0.010) appear to be caused to a great extent by the antidepressant medication the patients took (p when including amitriptyline into the analysis=0.990). These results confirm prior research that showed HRV to be reduced in medicated depressed samples (Kemp et al., 2010; Wang et al., 2013). On a subjective level, patients consistently perceived the stimuli as more negative and arousing in all three conditions (neutral, unpleasant, highly unpleasant).

In summary, two key findings of this study are an increased physiological arousal in response to emotionally evocative pictures as well as an intensified subjective perception of the stimuli in the patient sample. A possible explanation for these findings is that an increased physiological arousal, in fact, leads to an intensified perception of this information, which then aggravates depressive symptoms such as prolonged and intense phases of sadness. Such intense emotional states might be difficult to regulate, which then leads to an impairment of emotional and social competences.

4.2 Associations between emotion perception and depressive symptoms

This hypothesis is strengthened by our results concerning social and emotional deficits in depressed individuals. Patients described themselves as more socially sensitive (able to understand social messages etc.) than control subjects. However, they considered themselves less capable to be socially expressive (able to get in touch with others etc.) and to exhibit social control (master social situations of all sorts in a competent manner). This is in line with studies showing that depressed subjects exhibit less mimic expressions spontaneously (Gaebel and Wölwer, 1992) and that their facial expressions seem harder to decipher than those of healthy subjects (Prkachin et al., 1977). While patients reported better abilities to recognize their own emotions, they rated their capability to regulate their own emotions as lower. Assuming that depressed patients are constantly trying to regulate intense negative emotions while interacting with others, it seems plausible that they are more likely to send out confusing social signals than healthy individuals, which then might affect their ability to handle social interactions (Prkachin et al., 1977). This notion is in line with our findings of valence and arousal ratings being correlated with deficits in emotional competence, social skills and general depressive symptoms.

4.3 Limitations

An intensified emotion perception in depressed subjects as predicted in this study, might lead not only to accentuated breathing patterns but also to elevated TEMP and GSR levels while viewing unpleasant pictures. The fact that TEMP scores were elevated across measurements regardless of the level of negativity in the pictures while GSR levels did not differ at all between samples raises the question whether the stimuli used in our study induced enough stress. The IAPS battery provides a very well validated stimuli set from which we selected a subsample of pictures that were low or even very low in valence. Nevertheless, the media (daily news, internet etc.) provide us with pictures and video clips of negative content on a daily basis. Although one can categorize them as negative or arousing (such as depressed patients did in our study) they might not elicit the same kind of physiological reaction as processes such as habituation or detachment might attenuate the actual arousal. One task for further research, hence, would be to find a stress task that is actually eliciting an emotional stress response.

Another limitation of research into peripheral physiological arousal lies in other potential factors that vary between different studies such as age, menstrual cycle or comorbid somatic disorders that may bias findings of other work groups. However, we assessed all physiological measures under stable conditions, ensured patients did not consume nicotine or caffeine 12 hours prior to the measurement and used medication equivalent scores as well as other covariates in our analysis. Thus, we reduced the potential impact of person-situation-environment interactions. Yet, for further research menstrual cycle should be assessed as well in women.

Most patients were taking medication at the time of testing, which might have distorted our results. Taking into consideration, however, that antidepressant medication is recommended in mild to moderate depression and highly recommended in severe depression, especially when episodes are recurrent (American Psychiatric Association, 2010; Anderson et al., 2000; Reimherr et al., 1998; Young, 2001), selecting un-medicated patients bears the risk of testing an unrepresentative sample (milder depressive symptomatology, fewer depressive episodes). Thus, we consider choosing a sample of individuals suffering from recurrent depressive disorder currently experiencing an acute episode as a strength of this study. However, another possibility for future research would be to build subgroups and examine the influence of specific substance groups.

4.4 Conclusion

In summary, our findings suggest that depressed participants perceived the IAPS pictures in an intensified manner as compared to control subjects. This difference mainly manifests itself in altered breathing patterns as well as in the subjective ratings of valence and arousal. These results reveal differences in emotion perception between depressed and non-depressed individuals that have – to our best knowledge – not been investigated before. Such insights may help to understand how dysfunctional emotional processing contributes to emotional and social deficits in depression. To further examine the way depressed individuals react to emotional stress may shed light on diagnostic and therapeutic questions. As a potential therapeutic avenue, it may be possible to identify specific stressors that affect the ANS and influence those with specific training to reduce stress levels and improve clinical symptomatology. Ultimately, helping depressed people deal with emotional stress in a more functional and effective way might enhance their abilities to overcome social impairments and thereby improve their quality of life.

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Figure 1: a) sequential display of the emotion paradigm b) timeline of the procedure of assessing physiological arousal. *Abbreviations*: RSP = respiratory frequency; GSR = galvanic skin response; TEMP = skin temperature; HRV = heart rate variability.

Figure 2: Boxplots of the group comparison of patients and control subjects in the different measurement conditions (i.e., during the first baseline measurement, while looking at neutral, unpleasant and very unpleasant pictures and during the second baseline). Respiratory frequency (RSP) is demonstrated in breaths per minute, skin temperature (TEMP) in degrees Celsius (C°).

Note. The box represents the interquartile range, which contains the middle 50% of the scores as well as a line representing the median. The whiskers are lines that extend from the upper (75^{th} percentile) and lower (25^{th} percentile) edge of the box to the highest and lowest values which are no greater than 1.5 times the range. Extreme high values whose distance from the 75^{th} percentile is bigger than the distance from the 75^{th} percentile to the 25^{th} multiplied by 1.5 are marked as dots. Extreme low values are measured accordingly based on their distance from the 25^{th} percentile.

Figure 3: Boxplots of the group comparison of patients and control subjects for SDNN and RMSSD (in ms) in the different measurement conditions (i.e., during the first baseline measurement, while looking at neutral, unpleasant and very unpleasant pictures and during the second baseline). For a detailed description of the boxplot, see note to Figure 2.

Figure 4: Boxplots of the group comparison of patients and control subjects for subjective arousal and valence ratings in the different measurement conditions (i.e., while looking at neutral, unpleasant and very unpleasant pictures). Valence (i.e., negativity) and arousal were each measured on a scale from 0 to 10 via paper and pencil. For a detailed description of the boxplot, see note to Figure 2.

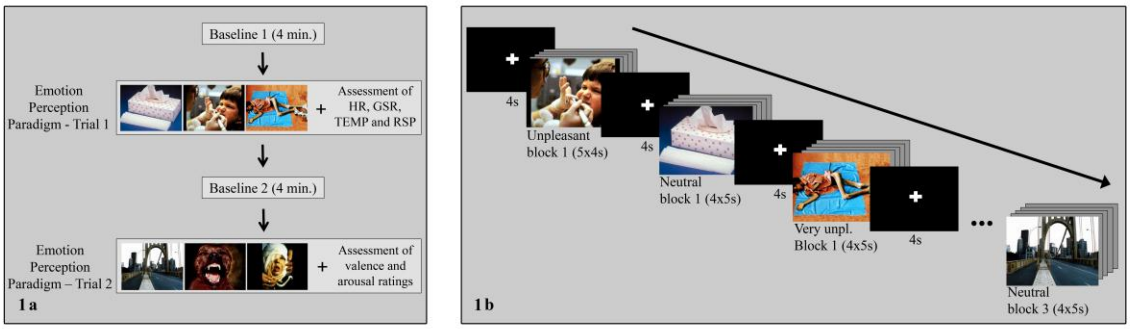
Figure 5: Overview of group comparisons of emotional competence (ECQ) and social skills (SSI). *Abbreviations*: ECQ= Emotional Competence Questionnaire; SSI= Social Skills Inventory; Patients ↑= significantly higher values in the patient group; Patients ↓= significantly lower values in the patient group.

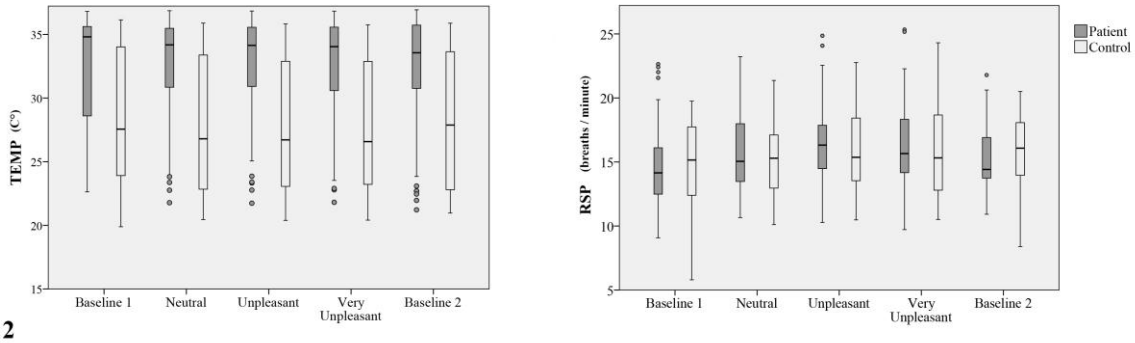
Table 1: Sociodemographic and clinical characteristics of the patient group and the control group. SD and range are in brackets. *Abbreviations:* BMI=body mass index; TMT-A=Trail Making Test A; BDI II=Beck-Depression scale; *M*=arithmetic mean; SD=standard deviation; PAT=patient group, CON=control group.

Sample Size	**CON** **M (SD)**	**PAT** **M (SD)**
Gender	42 29 female 13 male	41 25 female 16 male
Age (years)	40.67 (11.76)	43.85 (11.55)
BMI (kg/m^2)	23.81 (3.63)	26.56 (5.54)
Nicotine (cigarettes/day)	2.56 (6.72)	5.88 (8.79)
TMT-A	50.45 (7.96)	46.51 (10.49)
BDI II	2.14 (2.51)	22.66 (10.60)
Disease onset (age)		30.85 (14.08)
Illness duration (in years)		12.75 (13.11)
Number of depressive episodes		8.00 (10.44)
Years of taking antidepressant medication		2.34 (4.42)
Amitriptyline equivalent score		103.7 (95.9)
Chlorpromazine equivalent score		18.4 (81.8)

Highlights

- Emotion perception is intensified in recurrent depressive disorder.
- Intensified emotion perception is associated with increased physiological arousal.
- Skin temperature is elevated in recurrent depressive disorder.
- Intensified emotion perception is associated with social skill deficits in depression.





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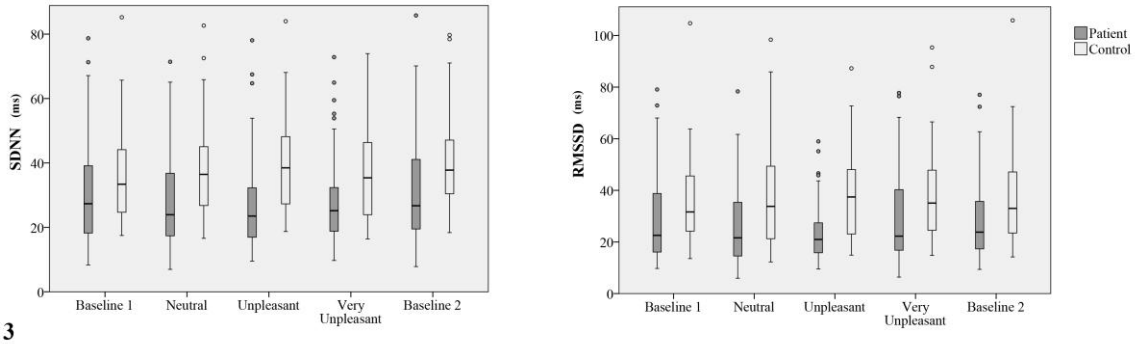

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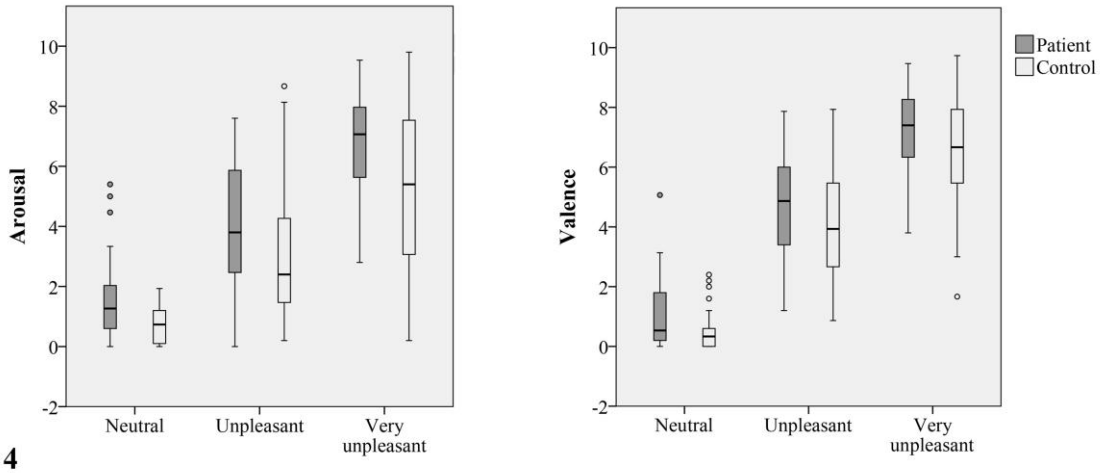

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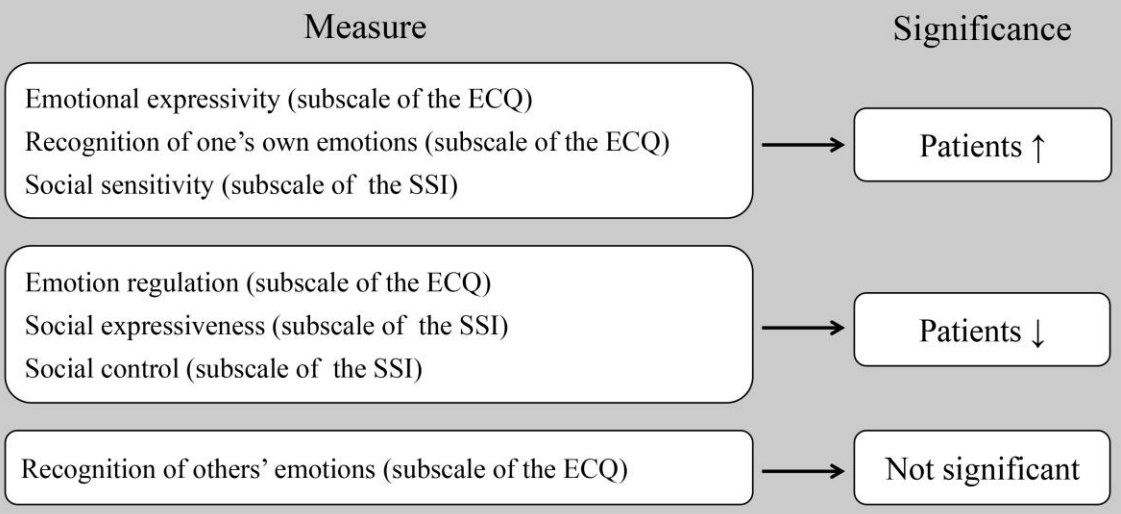

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