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Regulation of sadness via acceptance or suppression in adult Attention Deficit Hyperactivity Disorder (ADHD)

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ABSTRACT

Emotion dysregulation is a recognized symptom of adult Attention Deficit Hyperactivity Disorder (ADHD). The aim of this study is to induce sadness in adults suffering from ADHD and to investigate the impact of emotion regulation strategies on sadness intensity, and psychophysiological measures. Thirty-six adults diagnosed with ADHD were randomly assigned to either expressive suppression (SUPP) or acceptance (ACC) of emotion. Sadness was induced using a film clip. Participants estimated the intensity of sadness and the perception of being overwhelmed with emotion before (*T*1), immediately after (*T*2) and 2 min after the film (*T*3). Physiological measures were obtained. Sadness induction was effective in both conditions. The perception of being overwhelmed with emotion increased between *T*1 and *T*2 in both conditions, but persisted until *T*3 only in the expressive suppression condition whereas a decrease was observed in the acceptance condition. In ADHD expressive suppression of sadness seems to be associated to a prolonged recovery from the perception of being overwhelmed with emotion. Emotion-regulation via acceptance in contrast appears to allow faster recovery from the perception of being overwhelmed with emotion. To our knowledge, this is the first study to identify suppression as a critical mediator between an induced emotion and delayed recovery from emotional reactions in adult ADHD.

1. Introduction

Emotional symptoms such as lability of mood, emotional excitability, stress sensitivity and irritability are considered relevant components of Attention Deficit Hyperactivity Disorder (ADHD) symptomatology since the publication of the Wender Utah criteria (Wender et al., 1981) even if they have not been included in DSM-V (Barkley and Murphy, 2010; Sobanski et al., 2010; Surman et al., 2011; American Psychiatric Association, 2013; Corbisiero et al., 2013). Sjowall et al. (2013) provided evidence for the central importance of emotion regulation difficulties in ADHD children independent of neuropsychological impairments. Emotions seem to contribute to or aggravate distractability in individuals suffering from ADHD (Martel, 2009; Marx et al., 2011) via assumed emotion regulation deficits (Walcott and Landau, 2004; Desman et al., 2006; Berger et al., 2007; Bresner et al., 2009; Martel, 2009). Still the nature of deficient emotional self-regulation in ADHD is unknown (Musser et al., 2011). It might be characterized by deficits in regulating physiological reactions or problems inhibiting uncoordinated behavior tendencies and expressions or difficulties controlling and refocusing attention when emotional reactions have been triggered (Rash and Aguirre-Camacho, 2012). Bresner et al. (2009) described emotion-regulation difficulties in adult ADHD patients compared to age matched control subjects. They found heightened intensity concerning the perception of being overwhelmed by emotions in ADHD subjects. ADHD subjects reported to have little capacity to regulate and control emotions. This is in line with Wender's postulation of "overexcitability" in the Wender Utah criteria for adult ADHD (Wender et al., 2001). Moreover ADHD patients reported a significantly higher tendency to resignation and rumination (Bresner et al., 2009). Both, the perception of the acute emotional state, of the degree of control over emotional reactions and the regeneration process from emotional states, seem to be impaired in adult ADHD via rumination pathways.

From a therapeutical perspective it is desirable to enable patients suffering from ADHD to adaptively deal with their

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emotions, to teach them strategies to control the overwhelming intensity of emotional experience, the tendency to act out emotional reactions and the recovery from emotional states. Therefore we wanted to investigate on emotion regulation strategies which allow to control emotional reactions or to distance oneself from the emotional process. Thus, the impact of emotion regulation via expressive suppression (SUPP) vs. acceptance (ACC) on the intensity of and the recovery from an experimentally induced emotional state were investigated.

We assumed that expressive suppression of emotions requiring an active reduction of expressive behavioral emotional reactions (Gross and Levenson, 1997) might be a particularly challenging demand for individuals suffering from an externalizing disorder such as ADHD with the tendency to spontaneously express and act out emotions. Difficulties to suppress the expression of emotion have been shown for boys suffering from ADHD during a frustrating competitive Puzzle Task (Walcott and Landau, 2004). Boys suffering from ADHD and a control group were instructed to control their emotional expressions. ADHD participants were not able to conduct this task as successfully as the control group (Walcott and Landau, 2004).

Expressive suppression is known to have adaptive and maladaptive effects in healthy individuals (Gross, 1998; Bonanno et al., 2004; Dunn et al., 2009; Westphal et al., 2010). In individuals with the tendency to intensive emotional reactions expressive suppression might be a means to avoid uncontrolled emotional reactions which often have undesirable consequences: a study investigating on emotion regulation through acceptance and expressive suppression in women suffering from borderline personality disorder reported adaptive effects of expressive suppression concerning the urge for non-suicidal self-injury and the urge for self-punishment (Svaldi et al., 2012a). While expressive suppression reduces the external visible components of the emotional process, it does not mitigate the inner emotional experience of negative emotions, leads to increases in physiological responsiveness and seems to have cognitive costs (Gross and Levenson, 1997; Richards and Gross, 2000) in healthy individuals. In participants with psychiatric disorders increased negative emotion experience when suppressing and during a recovery period has been reported (Campbell-Sills et al., 2006a, 2006b). The increased negative emotion experience was dependent on participants' judgments of their emotions as unacceptable (Campbell-Sills et al., 2006a).

Acceptance as it is taught in therapeutic approaches such as dialectical behavioral therapy (Perroud et al., 2012) implies distancing from an emotional process as it is experienced from an observer perspective. To adopt an accepting attitude towards an emotion presupposes that an instance adopts this attitude and therefore that one is not fully immersed in the emotional process but perceives its course. For patients suffering from emotional dysregulation and the perception of uncontrollable and intensive emotional states acceptance might have regulating effects due to the distancing power of the observer perspective. The effect of acceptance on the inner emotional experiences and physiological responding remains subject of debate doubtlessly because the definitions of acceptance are various (Dunn et al., 2009). Dunn et al. (2009) found no difference in the subjective experience of emotions including sadness between an acceptance and a control condition in healthy individuals. In a study investigating on the effects of mindfulness-based stress reduction on emotion regulation in social anxiety disorder decreased negative emotion experience was found during breath-focused attention deployment emotion regulation (Goldin and Gross, 2010). In patients suffering from panic disorder acceptance lead to less subjective anxiety and reduced tendencies to avoid (Eifert and Heffner, 2003; Levitt et al., 2004). Studies by Campbell-Sills et al. (2006a, 2006b) in participants with mood and anxiety disorders found less reported negative affect during the recovery period after applying acceptance as emotion regulation strategy and decreased heart rate during the emotion regulation process (Campbell-Sills et al., 2006b).

It is evident that the autonomic nervous system plays an important role in self-regulation processes by modulating physiological arousal. Dysregulation of the autonomic nervous system going along with emotional dysregulation has been hypothesized for children with ADHD (for review see Rash and Aguirre-Camacho (2012). Rash and Aguirre-Camacho (2012) reported the results of six studies with a focus on the autonomic nervous system in ADHD children. Although evidence on cardiac vagal control in childhood ADHD is scarce and inconclusive (Rash and Aguirre-Camacho, 2012), the authors point to a probable accordance: cardiac vagal control seems to be lower in ADHD than in control children, a finding which might correspond to an inefficient parasympathetic responding to the situational demands of the environment (Porges, 2007). Musser et al. (2011) compared ADHD children to control children using an emotion task with two valences (positive vs. negative) and two conditions (induction vs. suppression), measuring autonomic nervous system variables during emotion regulation. The authors found altered respiratory sinus arrhythmia (RSA) reactivity, indexing parasympathetic influence on the heart, in children with ADHD compared to healthy control children especially when they were asked to suppress an induced negative emotion. Therefore the higher effort to suppress the expression of an emotion might also be mirrored on a psychophysiological level in ADHD subjects. ADHD and control group did not differ with regard to sympathetic activity as measured with cardiac pre-ejection period (PEP; Musser et al., 2011).

In adults with ADHD psychophysiological research on emotion regulation has not been reported so far. As research on emotion regulation in adults with ADHD is scarce, we wanted to focus on this field and decided to observe emotional and physiological alterations and reactions in response to the induction of the negative emotion of sadness and during recovery from the acute emotional state.

Taken into account the above depicted findings, hypotheses have been developed: first, it was hypothesized that compared to the acceptance condition the ADHD participants in the suppression condition would react with an increase in emotional intensity during induction and a prolonged recovery to baseline due to difficulties to suppress, probable self-judgements of failure and a tendency to rumination. Second, participants in the suppression conditions, compared to participants in the acceptance condition, were expected to show a significantly greater increase of the feeling of being overwhelmed with emotion because of the perception of their inability to control their emotional expressions. Third, we expected increased sympathetic activation in the suppression condition as suppression is known to have a disequilibrating impact on the autonomic nervous system inducing mixed physiological states with increased sympathetic activity (Gross and Levenson, 1997).

2. Methods

Adult participants with ADHD were recruited at the outpatient clinic of the Department for Psychiatry and Psychotherapy, University Medical Center Freiburg. The diagnosis of adult ADHD was established by means of a detailed psychiatric interview that integrates common psychiatric and somatic differential diagnoses and patients' medical histories. This procedure was recommended by the German guidelines for adult ADHD (Ebert et al., 2003). An experienced psychiatrist was in charge of the diagnostic procedure. Exclusion criteria were current substance abuse or dependence, organic psychiatric disorders, bipolar disorder, current or past psychosis, schizophrenia, current suicidal ideations and borderline personality disorder. All diagnoses were established by means of the Structured Clinical Interview for DSM-IV-Axis I (SCID I) and the paragraph from SCID II assessing diagnostic

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criteria for borderline personality disorder (SCID, (Spitzer et al., 1992), German version: (Wittchen et al., 1997). All participants, if treated with ADHD-specific medication, were asked to taper off these medications 48 h prior to the experiment.

The study was approved by the local ethics committee. Thirty-six adult participants with an ADHD diagnosis according to DSM-IV (American Psychiatric Association, 2000) gave their informed consent to participate in the study. They were randomly assigned to one of the two emotion regulation strategies.

2.1. Questionnaires

ADHD symptoms in childhood were self-rated retrospectively with the validated short version of the Wender Utah Rating Scale (WURS-k, Ward et al., 1993; German version Retz-Junginger et al., 2002). The WURS-k includes 25 items on a five-point Likert scale ("not at all" to "severe", cut-off score 30). Self-rating of current ADHD symptoms was conducted with the Conners Adult ADHD Rating Scales (CAARS-S:L; Conners et al., 1999, German version: Christiansen et al., 2011, 2012). The CAARS-S:L consists of 66 items (rated on a four-point Likert scale from "not at all/never" to " very often"). The Beck Depression Inventory (BDI; Beck et al., 1988, German version: Hautzinger et al., 1994) was employed to measure depressive symptoms; the maximum sum score amounts to 63. The Emotion Regulation Questionnaire (ERQ; Gross and John, 2003, German version: Abler and Kesser, 2009) is a validated 10 item self-report instrument allowing to measure two emotion regulation styles: suppression and reappraisal on a seven point rating scale for each item ranging from 1 (not at all true) to 7 (very true). Subscale scores for reappraisal and suppression are computed as mean scores of all item responses and therefore range between 1 and 7.

2.2. Emotion induction and experimental procedure

To induce sadness participants watched a film clip presented on a 17 in. monitor, 125 s in length, which had been pre-tested as stimulus material to induce the discrete emotion of sadness (Hahn et al., 1994; Rottenberg et al., 2007). The film clip involves the theme of loss of a beloved. The participants underwent the following procedure: first, they were given a standardized instruction (Gross and Levenson, 1993) either to suppress or to accept the upcoming emotion (Svaldi et al., 2012a). The wording of the instruction is given in the Appendix. To ensure that participants had enough time to read and understand the instruction, they had to press a button in order to continue with the experiment. After the instruction, self-report items (*T*1) were assessed using 100 mm Visual Analogue Scales (VAS). Then the film clip was presented, followed by a still image of the film clip, which remained on the screen for 20 s. Next, self-report items (*T*2) were re-assessed, followed by a block of 120 s in which landscape photographs were presented. Finally, self-report items were assessed once more (*T*3).

To assess compliance with the instructions participants had to rate two statements on a 100 mm VAS word-anchored at each end (very untrue–very true): "While watching the clip, I allowed my feelings to come" (acceptance compliance statement) and "While watching the clip, I concealed my feelings from others" (suppression compliance statement).

Based on the Wender Utah criterion "overexcitability" (Wender et al., 2001) and Bresner et al.'s (2009) results concerning the characteristic feeling of being overwhelmed by emotions in adults with ADHD the variable *I feel overwhelmed by my feelings* was used to measure emotional reaction and chosen as dependent variable. The feeling of being overwhelmed and sadness (*In this moment I feel sad*) were both rated on a 100 mm VAS (not at all–very much), before (*T*1), directly after the film clip (*T*2) and after watching neutral sceneries for 120 seconds (*T*3).

2.3. Psychophysiology

Heart rate (HR), respiratory frequency (RF), and pulse transit time (PTT) were assessed continuously. Due to the cardiovascular dynamic (Lackner et al., 2014), the physiological measures HR and PTT were computed in short intervals of 1 min. However, as suggested by the Task Force (1996), 2 min segments were used for high frequency heart rate variability (HF-HRV), low frequency heart rate variability (LF-HRV) and RF. Therefore, corresponding to the assessments of sadness and the feeling of being overwhelmed, PTT and HR were computed by averaging measurements taken in the minute before the acquisition of the variables, while a segment of 2 min before the rating of the variables was chosen for RF, HF-HRV and LF-HRV.

2.4. Data reduction

Psychophysiological measurements were executed following established conventions for psychophysiological research and published guidelines (Cacioppo et al., 2007). Psychophysiological channels were sampled continuously at 256 Hz using a Varioport system (Becker Meditec, Karlsruhe, Germany). The data were simultaneously streamed to disk and displayed on a PC monitor for online artefact control. Offline, data inspection and artefact rejection were performed using ANSLAB (Wilhelm and Peyk, 2005). Offline, data inspection and artefact rejection of beat-to-beat values were done semi-automatically with a signal analyzer developed in MATLAB® (Lackner et al., 2010).

2.4.1. Heart rate (HR)

To obtain heart rate series with equidistant time steps, the beat to beat values were resampled with 4 Hz using piecewise cubic spline interpolation after artifact correction. Single artifacts were replaced by interpolation (on average less than 0.5% of the data) and its appearance was recorded.

2.4.2. HF-HRV and LF-HRV

For frequency domain indexes of the interbeat interval IBI series for each segment, the autoregressive Burg algorithm (model order 24) after resampling and removing the linear trend was used (Svaldi et al., 2012b). Low frequency (LF) was defined as 0.04–0.15 Hz and high frequency (HF-HRV) was defined as 0.15–0.40 Hz, according to published recommendations (Task Force, 1996). Because of skewed distributions of the frequency domain variables, a natural logarithmic transformation (ln) was applied.

2.4.3. Pulse

PTT (in milliseconds) was indexed by time elapsed between the closest previous ECG R-wave and the steepest upstroke of the peripheral pulse at the finger.

2.5. Data analysis

Groups were compared for age, gender, years of education, marital and occupational status, income, comorbidities as well as psychometric scores using one way analysis of variance (ANOVA) or χ^2-tests. To check for differences between the two emotion regulation strategies repeated measures analyses of variance (ANOVAs) were used with factor group (SUPP: suppression vs. ACC: acceptance) and sadness, accordingly feeling of being overwhelmed and psychophysiological measures as dependent variables. One-way ANOVAs, including post-hoc analyses, were conducted for further investigation of group differences between the emotion regulation strategies.

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3. Results

3.1. Manipulation check and sadness intensity changes

There were no significant differences depending on strategy on any of the self-report and psychophysiological data. The sadness induction via film-clip was effective (see Fig. 1). For the dependent variable sadness a 2 (strategy: SUPP, ACC) × 3 (time: *T*1, *T*2, *T*3) ANOVA revealed a significant effect of time ($F_{1,34}=25.239$, $P<0.001$), no significant effect of strategy ($F_{1,34}=0.866$, $P=0.359$) and no interaction of strategy × time ($F_{1,34}=1.321$, $P=0.281$). Sadness intensity was independent of emotion regulation strategy. Overall perceived sadness increased from *T*1 to *T*2 (*M*/S.D.; *T*1: 8.53/15.09, *T*2: 47.28/33.72; $t_{1,35}=-6.991$, $P<0.001$) and decreased from *T*2 to *T*3 (*M*/S.D.; *T*2: 47.28/33.72, *T*3: 16.50/18.81; $t_{1,35}=5.094$, $P<0.001$).

3.2. Feelings of being overwhelmed by emotions during the course of the experiment (see Fig. 2)

For the dependent variable feeling of being overwhelmed by emotion a 2 (strategy: SUPP, ACC) × 3 (time: *T*1, *T*2, *T*3) ANOVA revealed a significant interaction of strategy × time ($F_{2,66}=7.031$, $P<0.050$), a significant main effect of time ($F_{1,33}=7.691$, $P<0.050$) and no significant effect of strategy ($F_{2,66}=0.087$, $P=0.770$).

To test the most relevant differences, *t*-tests have been performed for both strategies separately. In the group which performed suppression the feeling of being overwhelmed increased significantly from *T*1 to *T*2 (*M*/S.D.; *T*1: 11.17/14.64, *T*2: 30.22/32.71; $t_{1,17}=-2.372$, $P<0.05$) and decreased non-significantly from *T*2 to *T*3 (*M*/S.D.; *T*2: 30.22/32.71, *T*3: 26.61/26.97; $t_{1,17}=0.429$, $P=0.673$). In the acceptance group the feeling of being overwhelmed increased significantly from *T*1 to *T*2 (*M*/S.D.; *T*1: 22.17/26.57, *T*2: 43.33/34.39; $t_{1,17}=-3.395$, $P<0.05$) and decreased significantly from *T*2 to *T*3 (*M*/S.D.; *T*2: 43.33/34.39, *T*3: 8.11/10.71; $t_{1,17}=4.200$, $P<0.05$).

Overall participants in the two conditions did not differ in level of the feeling of being overwhelmed at *T*1 (*M*/S.D.; SUPP: 11.17/14.64, ACC: 22.17/26.57, $t_{1,34}=1.54$, $P=0.136$) and *T*2 (*M*/S.D.; SUPP: 30.22/32.71, ACC: 43.33/34.39, $t_{1,34}=1.17$, $P=0.249$) but there was a significant difference in level of the variable at *T*3 (*M*/S.D.; SUPP: 26.61/26.97, ACC: 8.11/10.71, $t_{1,34}=-2.71$, $P<0.050$; see Fig. 2).

3.3. Course of psychophysiological measures

HR, PTT, LF-HRV, HF-HRV (see Table 1) changed significantly over time including measures at *T*1, *T*2 and *T*3. There were no significant interactions of strategy × time. Following *t*-tests revealed a significant decrease in HR from *T*1 to *T*2 ($t_{1,34}=5.665$, $P<0.010$), paralleling the sadness induction, and no change from *T*2 to *T*3 ($t_{1,34}=-1.538$, $P=0.133$). PTT increased from *T*1 to *T*2 ($t_{1,34}=-3.485$, $P<0.050$) as well as from *T*2 to *T*3 ($t_{1,34}=-2.720$, $P<0.050$). LF-HRV did not change from *T*1 to *T*2 ($t_{1,34}=-0.296$, $P=0.769$) but increased significantly from *T*2 to *T*3 ($t_{1,34}=-2.773$, $P<0.050$). Overall HF-HRV increased ($t_{1,34}=-3.716$, $P<0.050$). For respiratory frequency a significant main effect of time ($F_{2,66}=20.219$, $P<0.001$) and time × strategy ($F_{2,66}=3.631$, $P<0.05$) and no significant effect of strategy ($F_{2,66}=0.001$, $P=0.977$) were found. Post-hoc *t*-tests conducted separately for the strategies revealed no change in RF from *T*1 to *T*2 in ACC ($t_{1,34}=0.675$, $P=0.509$) but a significant decrease of RF in SUPP ($t_{1,34}=3.646$, $P<0.050$).

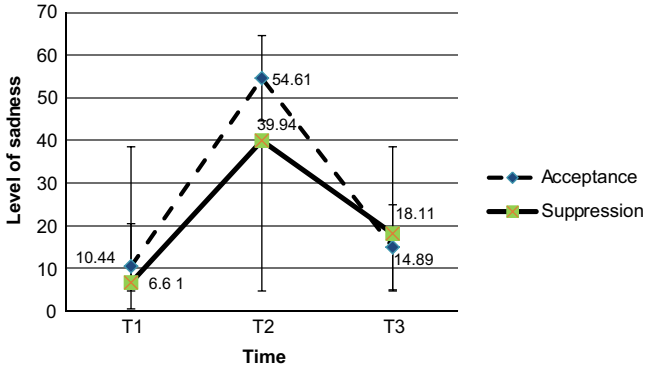

Fig. 1. Group comparison between ACC and SUPP concerning level of induced sadness (Mean, S.D.).

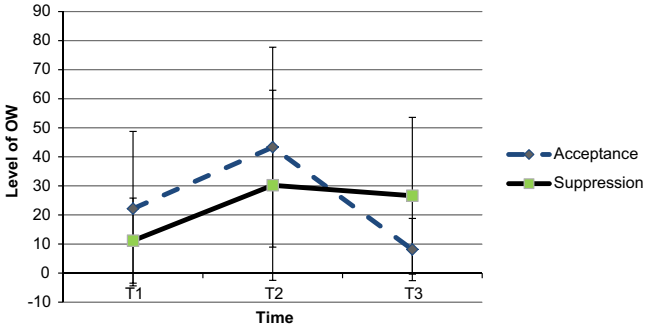

Fig. 2. Group comparison between ACC and SUPP concerning level of the feeling of being overwhelmed by emotions (Mean, S.D.).

3.4. Compliance ratings

t-tests were conducted to compare the ratings of an acceptance compliance statement and a suppression compliance statement between the conditions. The manipulation check revealed that participants in the ACC allowed their emotions to come if compared to the participants in the SUPP ($t_{1,34}=2.54$, $P<0.050$) whereas participants in the SUPP concealed their feelings from others if compared to the participants in the ACC ($t_{1,34}=-2.04$, $P<0.050$).

3.5. Participants' characteristics

There were no significant differences between the participants in the two conditions with regard to age (years *M*/S.D.; SUPP: 38.06/11.91; ACC: 36.67/10.75; $F_{1,35}=0.135$, $P=0.716$), gender (SUPP: $n=8$ males, ACC: $n=9$ males; $\chi^2=0.111$, $P=0.738$), years of education (years *M*/S.D.; SUPP: 14.529/ 3.555; ACC: 14.357/ 2.499; $F_{1,30}=0.023$, $P=0.880$), marital ($\chi^2=1.491$, $P=0.828$) and occupational ($\chi^2=2.200$, $P=0.900$) status, income ($\chi^2=7.485$, $P=0.278$), comorbidities as well as scores on the WURS-k, CAARS-S:L, BDI and ERQ subscales and the familiarity with the film (all $Fs<2.037$, all χ^2s <7.485, all $Ps>0.163$).

Consistent with the literature (Kessler et al., 2006), overall comorbidity was high. Only 11.1% of the entire sample had no comorbidity. Specifically, 13.9% of the sample had a diagnosis of current major depression, 52.8% of a past major depression, 8.3% of a current minor depression, 5.6% of a past minor depression, 8.3% had a current dysthymia and 2.8% a past dysthymia, 5.6% had past alcohol abuse and 19.4% a past alcohol dependence, 16.7% had a diagnosis of past substance abuse and 22.2% of past substance dependence, 2.8% of panic disorder, 2.8% of panic disorder with agoraphobia and 2.8% of agoraphobia, 5.6% of social phobia, 2.8% of somatoform disorder, 2.8% of bulimia, 19.4% of specific phobia and 2.8% of obsessive–compulsive disorder.

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Table 1
Means of psychophysiological parameters in response to the sadness inducing film clip (±standard deviation) and results of the repeated measures ANOVA analyses.

	Acceptance $N=18$			Suppression $N=18$			2 (strategy) × 3 (time: *T1*, *T2*, *T3*) repeated measures ANOVA			
							Time		Strategy × time	
	T1	*T2*	*T3*	*T1*	*T2*	*T3*	$F_{1,33}$	*P*	$F_{1,33}$	*P*
HR (bpm)	73.72 ± 11.38	68.03 ± 11.18	68.34 ± 9.73	71.26 ± 9.28	66.71 ± 9.59	68.66 ± 9.99	16.413	< 0.01	0.818	n.s.
PTT (ms)	267.88 ± 26.25	270.39 ± 26.49	273.27 ± 26.03	271.68 ± 15.74	275.47 ± 17.03	277.77 ± 17.90	9.972	< 0.01	0.273	n.s.
LF-HRV (ms^2)	6.56 ± 0.81	6.60 ± 1.26	6.95 ± 1.15	6.71 ± 0.71	6.75 ± 0.56	7.01 ± 0.86	5.324	< 0.05	0.101	n.s.
RF (breaths per minute)	17.70 ± 2.73	17.29 ± 3.46	15.45 ± 2.73	18.82 ± 3.31	16.09 ± 2.59	15.60 ± 2.50	20.219	< 0.001	3.631	< 0.05
HF-HFV (ms^2)	5.65 ± 1.26	5.56 ± 1.46	5.97 ± 1.45	5.85 ± 0.69	6.22 ± 0.69	6.25 ± 0.71	7.08	< 0.05	1.366	n.s.

Note: HF=heart rate; PTT=pulse transit time; HF-HRV=high frequency heart rate variability; LF-HRV=low frequency HRV; RF=respiratory frequency.

4. Discussion

The major aim of this study was to investigate the effect of two emotion regulation strategies (expressive suppression vs. acceptance) in adult participants suffering from ADHD to detect possible interrelations of negative emotional states and ADHD-related "overexcitability", operationalized as the feeling of being overwhelmed by emotion. Based on the results of Walcott's study (Walcott and Landau, 2004) reporting difficulties in ADHD children to successfully suppress expressive emotional behavior and on Bresner et al. (2009) findings suggesting a more intensive experience and prolonged cognitive preoccupation with emotional reactions in adults suffering from ADHD we expected a more intensive experience of sadness in the suppression condition and a prolonged recovery.

Contrary to our hypothesis we found no significant difference in the course of sadness intensity during the experiment between suppression and acceptance. Emotion regulation strategy did not impact the experience of emotional intensity, a finding which is in line with studies in healthy subjects (Gross and Levenson, 1993; Demaree et al., 2006; Robinson and Demaree, 2009) but conflicts with Campbell-Sills et al. (2006a) report of the association between suppression and increased negative emotion experience in a clinical sample.

According to our second hypothesis, based on the result of Bresner et al. (2009) study and on the assumption that adults suffering from ADHD might feel overwhelmed with emotion during suppression because of the perception of their failure to suppress their emotional expressions we expected participants in the suppression condition, compared to participants in the acceptance condition, to show a significantly greater increase of the feeling of being overwhelmed with emotion during the emotion induction. We detected a prolonged recovery from the feeling of being overwhelmed from *T2* to *T3* in the suppression condition. In the acceptance condition on the contrary a significant decrease of the feeling of being overwhelmed during recovery was observed. ADHD individuals with their tendency to spontaneously express emotions struggle with the demand to inhibit their emotional expressions (Walcott and Landau, 2004). We assumed that adults more than children with ADHD might be simultaneously aware of the struggle and their difficulties to inhibit emotional responses. The assumed perception of being unable to suppress emotional expressions seems to be associated to a persistent internal perception of the feeling of being overwhelmed. This might be due to negative self-validation processes in ADHD individuals (Newark et al., 2012). Acceptance of the upcoming emotion on the contrary seems to reduce the perception of the feeling of being overwhelmed after the neutralizing period suggesting a more rapid decrease of such negative self-validation processes.

Third, as suppression is known to have a disequilibrating impact on the autonomic nervous system inducing mixed physiological states with increased sympathetic activity (Gross and Levenson, 1997) we expected increased sympathetic activation in the suppression condition. However, in both conditions a decrease of heart rate, a significant increase of PTT and the increase of LF-HRV between *T2* and *T3* indicate a decrease of sympathetic activation. An increase of sympathetic activation in the suppression condition was not found which might be in line with the presumption that individuals suffering from ADHD fail to suppress. The deceleration of heart rate over time might also reflect a consequence of sadness induction because sadness as an emotion of withdrawal leads to similar findings in healthy adults (Kreibig et al., 2007). But the lack of a control condition makes conclusions about the effects of sadness itself impossible. It cannot be excluded that the changes over time correspond to a habituation effect to the situation.

Similar considerations might be true with concern of parasympathetic regulation. Overall on the parasympathetic branch HF-HRV increased significantly and RF decreased as a sign of vagal activity. Again the decrease in RF can be expected in a state of sadness (Boiten et al., 1994) even if habituation effects cannot be excluded. Emotion regulation condition did influence RF during the sadness induction: suppressing individuals experienced a significantly more pronounced decrease in RF compared to the individuals applying acceptance. The physiological response showing a preponderance of parasympathetic activity in the suppression condition—the decrease in RF—might be a result of the unsuccessful effort to suppress on the psychophysiological level, mirroring a more pronounced psychophysiological sadness-pattern even if subjective ratings of sadness showed no difference between the acceptance and the suppression conditions. The finding as well as the invariance in measures of sympathetic activation between conditions might support the idea of ADHD individuals failing to successfully suppress the induced emotion.

The more pronounced parasympathetic reaction might also reflect abnormal parasympathetic mechanisms that have been found in unmedicated ADHD children (Tonhajzerova et al., 2009; Imeraj et al., 2011; Musser et al., 2011). The finding might be in line with a study reporting sympathetic underarousal and parasympathetic overarousal at baseline in children with ADHD in comparison to control subjects (Negrao et al., 2011). Changes under emotion regulation conditions have not been investigated in this study. Again the interpretability of our findings remains limited because of the lack of a healthy control group.

As comorbidities were frequent in our sample, effects of comorbid conditions on our findings cannot be excluded. Especially affective disorders are known to alter emotional responsivity (Bylsma et al., 2008). Reduced emotional reactivity and poorer

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recovery have been found in major depressive disorder for self-reported experience, expressive behavior, and peripheral physiology (Bylsma et al., 2008). Therefore attenuated response patterns due to comorbid depressive disorders are possible factors of influence in this study even if depressive symptom load as measured with the BDI did not differ significantly between the suppression and acceptance conditions.

There are some important limitations of our study besides small sample size: the lack of a healthy control group makes conclusions about the specific characteristics of emotion regulation in ADHD impossible, and the lack of a control condition of neutral stimulation makes conclusions about the effects of sadness impossible. Moreover the effect of comorbidities on emotion regulation cannot be excluded. Feelings of being overwhelmed by emotion were generally low. Therefore one initial point of our study based on Bresner's findings (Bresner et al., 2009) was not fully met.

To our knowledge this is the first study showing the short-term impact of different emotion regulation strategies on the intensity of sadness and the perception of being overwhelmed with emotions in adult ADHD. In conclusion, in this study suppression of a negative emotion did prolong the perception of being overwhelmed with emotions, whereas a reduction of the perception of being overwhelmed could be shown in the acceptance condition during the recovery process. Physiological results remain inconclusive but show a difference between the emotion regulation strategies for RF which undergoes a significant and pronounced decrease during sadness induction especially in the suppressing participants. Physiological responding during emotion regulation in adults with ADHD needs to be further investigated in comparison to healthy subjects to allow conclusions on ADHD-specific patterns during emotion regulation.

Appendix A. Standardized instructions for emotion regulation strategies

The instruction for the suppression condition read as follows: “While you watch the following film clips, different emotions and sensations may come. Please try your best not to let those feelings show. In other words try to behave in such a way that a person watching you would not know you were feeling anything. Please try now to develop a sentence which could help you to adopt this strategy as you are watching the clips, e.g. by telling yourself ‘Nobody should see the way I feel’ or ‘I am going to hide my feelings’ or maybe ‘I try not to let on about anything, so nobody can appraise the way I feel right now’. Experiment with your phrase, until you find one which really convinces you. Write then down your sentence on the sheet in front of you.” The instruction for the acceptance condition read as follows: “While you watch the following film clips, try to be aware of the sensations and emotions that are about to come. Allow yourself to have these emotions, even though you may experience some of them being problematic. While you are watching the film clips, try to accept upcoming emotions and try to experience them. Please try now to develop a sentence which could help you to adopt this strategy as you are watching the clips, e.g. by telling yourself ‘I accept these feelings and allow myself to experience them’, or ‘I am able to tolerate this feeling’, maybe also ‘It is alright that I feel the way I do right now, … I am entitled to experience my feelings and I am able to tolerate them’. Experiment with your phrase, until you find one which really convinces you. Write then down your sentence on the sheet in front of you.”

References

Abler, B., Kesser, H., 2009. Emotion Regulation Questionnaire—Eine deutschsprachige Fassung des ERQ von Gross und John. Diagnostica 55, 144–152.

American Psychiatric Association, 2000. (Text Revision). Diagnostic and Statistical Manual of Mental Disorders. American Psychiatric Association, Washington, DC.

American Psychiatric Association, 2013. Diagnostic and Statistical Manual of Mental Disorders, fifth edition American Psychiatric Association, Arlington, VA.

Barkley, R.A., Murphy, K.R., 2010. Deficient emotional self-regulation in adults with attention-deficit/hyperactivity disorder (ADHD): the relative contributions of emotional impulsiveness and ADHD symptoms to adaptive impairments in major life activities. Journal of ADHD and Related Disorders 1, 5–28.

Beck, A.T., Steer, R.A., Garbin, M.G., 1988. Psychometric properties of the Beck Depression Inventory: twenty-five years of evaluation. Psychology Review 8, 77–100.

Berger, A., Kofman, O., Livneh, U., Henik, A., 2007. Multidisciplinary perspectives on attention and the development of self-regulation. Progress in Neurobiology 82, 256–286.

Boiten, F.A., Frijda, N.H., Wientjes, C.J., 1994. Emotions and respiratory patterns: review and critical analysis. International Journal of Psychophysiology 17, 103–128.

Bonanno, G.A., Papa, A., Lalande, K., Westphal, M., Coifman, K., 2004. The importance of being flexible: the ability to both enhance and suppress emotional expression predicts long-term adjustment. Psychological Science 15, 482–487.

Bylsma, L.M., Morris, B.H., Rottenberg, J., 2008. A meta-analysis of emotional reactivity in major depressive disorder. Clinical Psychology Review 28, 676–691.

Bresner, T., Moussa, W., Reschke, K., 2009. Emotionsregulation von Erwachsenen mit Aufmerksamkeitsdefizit-/Hyperaktivitätsstörung (ADHS). Shaker, Aachen.

Cacioppo, J.T., Tassinary, L., Berntson, G.G., 2007. Handbook of Psychophysiology, 3rd ed. Cambridge University Press, Cambridge.

Campbell-Sills, L., Barlow, D.H., Brown, T.A., Hofmann, S.G., 2006a. Acceptability and suppression of negative emotion in anxiety and mood disorders. Emotion 6, 587–595.

Campbell-Sills, L., Barlow, D.H., Brown, T.A., Hofmann, S.G., 2006b. Effects of suppression and acceptance on emotional responses of individuals with anxiety and mood disorders. Behavior Research and Therapy 44, 1251–1263.

Christiansen, H., Kis, B., Hirsch, O., Matthies, S., Hebebrand, J., Uekermann, J., Abdel-Hamid, M., Kraemer, M., Wiltfang, J., Graf, E., Colla, M., Sobanski, E., Alm, B., Rosler, M., Jacob, C., Jans, T., Huss, M., Schimmelmann, B.G., Philipsen, A., 2012. German validation of the Conners Adult ADHD Rating Scales (CAARS) II: reliability, validity, diagnostic sensitivity and specificity. European Psychiatry 27, 321–328.

Christiansen, H., Kis, B., Hirsch, O., Philipsen, A., Henneck, M., Panczuk, A., Pietrowsky, R., Hebebrand, J., Schimmelmann, B.G., 2011. German validation of the Conners Adult ADHD Rating Scales-self-report (CAARS-S) I: factor structure and normative data. European Psychiatry 26, 100–107.

Conners, C.K., Erhardt, D., Epstein, J.N., Parker, J.D.A., Sitarenios, G., Sparrow, E., 1999. Self-ratings of ADHD symptoms in adults I: factor structure and normative data. Journal of Attention Disorders 3, 141.

Corbisiero, S., Stieglitz, R.D., Retz, W., Rosler, M., 2013. Is emotional dysregulation part of the psychopathology of ADHD in adults? Attention Deficit Hyperactivity Disorder 5, 83–92.

Demaree, H.A., Schmeichel, B.J., Robinson, J.L., Pu, J., Everhart, D.E., Berntson, G.G., 2006. Up- and down-regulating facial disgust: affective, vagal, sympathetic, and respiratory consequences. Biological Psychology 71, 90–99.

Desman, C., Schneider, A., Ziegler-Kirbach, E., Petermann, F., Mohr, B., Hampel, P., 2006. Behavioural inhibition and emotion regulation among boys with ADHD during a go-/nogo-task. Praxis der Kinderpsychologie und Kinderpsychiatrie 55, 328–349.

Dunn, B.D., Billotti, D., Murphy, V., Dalgleish, T., 2009. The consequences of effortful emotion regulation when processing distressing material: a comparison of suppression and acceptance. Behavior Research and Therapy 47, 761–773.

Ebert, D., Krause, J., Roth-Sackenheim, C., 2003. ADHD in adulthood—guidelines based on expert consensus with DGPPN support. Der Nervenarzt 74, 939–946.

Eifert, G.H., Heffner, M., 2003. The effects of acceptance versus control contexts on avoidance of panic-related symptoms. Journal of Behavior Therapy and Experimental Psychiatry 34, 293–312.

Goldin, P.R., Gross, J.J., 2010. Effects of mindfulness-based stress reduction (MBSR) on emotion regulation in social anxiety disorder. Emotion 10, 83–91.

Gross, J.J., 1998. Antecedent- and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. Journal of Personality and Social Psychology 74, 224–237.

Gross, J.J., John, O.P., 2003. Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. Journal of Personality and Social Psychology 85, 348–362.

Gross, J.J., Levenson, R.W., 1993. Emotional suppression: physiology, self-report, and expressive behavior. Journal of Personality and Social Psychology 64, 970–986.

Gross, J.J., Levenson, R.W., 1997. Hiding feelings: the acute effects of inhibiting negative and positive emotion. Journal of Abnormal Psychology 106, 95–103.

Hahn, D.P., Allers, R., Minkoff, R.D., 1994. The Lion King [Motion Picture]. Walt Disney Pictures, United States.

Hautzinger, M., Bailer, M., Worall, H., Keller, F., 1994. Beck Depressionsinventar. Hogrefe, Goettingen.

Imeraj, L., Antrop, I., Roeyers, H., Deschepper, E., Bal, S., Deboutte, D., 2011. Diurnal variations in arousal: a naturalistic heart rate study in children with ADHD. European Child and Adolescent Psychiatry 20, 381–392.

Kessler, R.C., Adler, L., Barkley, R., Biederman, J., Conners, C.K., Demler, O., Faraone, S.V., Greenhill, L.L., Howes, M.J., Secnik, K., Spencer, T., Ustun, T.B., Walters, E.E.,

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Zaslavsky, T., 2006. The prevalence and correlates of adult ADHD in the United States: results from the National Comorbidity Survey Replication. American Journal of Psychiatry 163, 716–723.
Kreibig, S.D., Wilhelm, F.H., Roth, W.T., Gross, J.J., 2007. Cardiovascular, electrodermal, and respiratory response patterns to fear- and sadness-inducing films. Psychophysiology 44, 787–806.
Lackner, H.K., Batzel, J.J., Rössler, A., Hinghofer-Szalkay, H., Papousek, I., 2014. Multi-time scale perspective in analysing cardiovascular data. Physiological Research, [Epub ahead of print].
Lackner, H.K., Goswami, N., Papousek, I., Roessler, A., Grasser, E.K., Montani, J.P., Jezova, D., Hinghofer-Szalkay, H., 2010. Time course of cardiovascular responses induced by mental and orthostatic challenges. International Journal of Psychophysiology 75 (1), 48–53.
Levitt, J.T., Brown, T.A., Orsillo, S.M., Barlow, D.H., 2004. The effects of acceptance versus suppression of emotion on subjective and psychophysiological response to carbon dioxide challenge in patients with panic disorder. Behavior Therapy 35, 747–766.
Martel, M.M., 2009. Research review: a new perspective on attention-deficit/hyperactivity disorder: emotion dysregulation and trait models. Journal of Child Psychology and Psychiatry 50, 1042–1051.
Marx, I., Domes, G., Havenstein, C., Berger, C., Schulze, L., Herpertz, S.C., 2011. Enhanced emotional interference on working memory performance in adults with ADHD. World Journal of Biological Psychiatry Suppl 1, 70–75.
Musser, E.D., Backs, R.W., Schmitt, C.F., Ablow, J.C., Measelle, J.R., Nigg, J.T., 2011. Emotion regulation via the autonomic nervous system in children with attention-deficit/hyperactivity disorder (ADHD). Journal of Abnormal Child Psychology 39, 841–852.
Negrao, B.L., Bipath, P., van der, W.D., Viljoen, M., 2011. Autonomic correlates at rest and during evoked attention in children with attention-deficit/hyperactivity disorder and effects of methylphenidate. Neuropsychobiology 63, 82–91.
Newark, P.E., Elsässer, M., Stieglitz, R.-D., 2012. Self-Esteem, Self-Efficacy, and Resources in Adults With ADHD. Journal of Attention Disorders, [Epub ahead of print].
Perroud, N., Nicastro, R., Jermann, F., Huguelet, P., 2012. Mindfulness skills in borderline personality disorder patients during dialectical behavior therapy: preliminary results. International Journal of Psychiatry in Clinical Practice 16, 189–196.
Porges, S.W., 2007. A phylogenetic journey through the vague and ambiguous Xth cranial nerve: a commentary on contemporary heart rate variability research. Biological Psychology 74, 301–307.
Rash, J.A., Aguirre-Camacho, A., 2012. Attention-deficit hyperactivity disorder and cardiac vagal control: a systematic review. Attention Deficit Hyperactivity Disorder 4, 167–177.
Retz-Junginger, P., Retz, W., Blocher, D., Weijers, H.G., Trott, G.E., Wender, P.H., Rossler, M., 2002. Wender Utah rating scale. The short-version for the assessment of the attention-deficit hyperactivity disorder in adults. Der Nervenarzt 73, 830–838.
Richards, J.M., Gross, J.J., 2000. Emotion regulation and memory: the cognitive costs of keeping one's cool. Journal of Personality and Social Psychology 79, 410–424.
Robinson, J.L., Demaree, H.A., 2009. Experiencing and regulating sadness: physiological and cognitive effects. Brain and Cognition 70, 13–20.
Rottenberg, J., Ray, R.D., Gross, J.J., 2007. Emotion elicitation using films. In: Coan, J. A., Allen, J.J.B. (Eds.), The Handbook of Emotion Elicitation and Assessment. Oxford University Press, London.
Sjowall, D., Roth, L., Lindqvist, S., Thorell, L.B., 2013. Multiple deficits in ADHD: executive dysfunction, delay aversion, reaction time variability, and emotional deficits. Journal of Child Psychology and Psychiatry, 54619–54627.
Sobanski, E., Banaschewski, T., Asherson, P., Buitelaar, J., Chen, W., Franke, B., Holtmann, M., Krumm, B., Sergeant, J., Sonuga-Barke, E., Stringaris, A., Taylor, E., Anney, R., Ebstein, R.P., Gill, M., Miranda, A., Mulas, F., Oades, R.D., Roeyers, H., Rothenberger, A., Steinhausen, H.C., Faraone, S.V., 2010. Emotional lability in children and adolescents with attention deficit/hyperactivity disorder (ADHD): clinical correlates and familial prevalence. Journal of Child Psychology and Psychiatry 51, 915–923.
Spitzer, R.L., Williams, J.B., Gibbon, M., First, M.B., 1992. The Structured Clinical Interview for DSM-III-R (SCID). I: history, rationale, and description. Archives of General Psychiatry 49, 624–629.
Surman, C.B., Biederman, J., Spencer, T., Yorks, D., Miller, C.A., Petty, C.R., Faraone, S. V., 2011. Deficient emotional self-regulation and adult attention deficit hyperactivity disorder: a family risk analysis. American Journal of Psychiatry 168, 617–623.
Svaldi, J., Dorn, C., Matthies, S., Philipsen, A., 2012a. Effects of suppression and acceptance of sadness on the urge for non-suicidal self-injury and self-punishment. Psychiatry Research 200, 404–416.
Svaldi, J., Tuschen-Caffier, B., Lackner, H.K., Zimmermann, S., Naumann, E., 2012b. The effects of emotion regulation on the desire to overeat in restrained eaters. Appetite 59, 256–263.
Task Force, 1996. Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. European Heart Journal 17, 354–381.
Tonhajzerova, I., Ondrejka, I., Adamik, P., Hruby, R., Javorka, M., Trunkvalterova, Z., Mokra, D., Javorka, K., 2009. Changes in the cardiac autonomic regulation in children with attention deficit hyperactivity disorder (ADHD). Indian Journal of Medical Research 130, 44–50.
Walcott, C.M., Landau, S., 2004. The relation between disinhibition and emotion regulation in boys with attention deficit hyperactivity disorder. Journal of Clinical Child and Adolescent Psychology 33, 772–782.
Ward, M.F., Wender, P.H., Reimherr, F.W., 1993. The Wender Utah rating scale: an aid in the retrospective diagnosis of childhood attention deficit hyperactivity disorder. American Journal of Psychiatry 150, 885–890.
Wender, P.H., Wolf, L.E., Wasserstein, J., 2001. Adults with ADHD. An overview. Annals of the New York Academy of Sciences 931, 1–16.
Wender, P.H., Reimherr, F.W., Wood, D.R., 1981. Attention deficit disorder ('minimal brain dysfunction') in adults: a replication study of diagnosis and drug treatment. Archives of General Psychiatry 38, 449–456.
Westphal, M., Seivert, N.H., Bonanno, G.A., 2010. Expressive flexibility. Emotion 10, 92–100.
Wilhelm, F.H., Peyk, P., 2005. ANSLAB 4.0: Autonomic Nervous System Laboratory. ⟨http://www2.psycho.unibas.ch/index_html?content=anslab⟩.
Wittchen, H.U., Zaudig, M., Fydrich, T., 1997. Strukturiertes klinisches Interview für DSM-IV: SKID; eine deutschsprachige, erweiterte Bearbeitung der amerikanischen Originalversion des SCID. Hogrefe, Göttingen.

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