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Summary of Ph.D. Thesis

INDIVIDUAL DIFFERENCES IN EMOTION REGULATION: PSYCHOLOGICAL AND BIOLOGICAL DIMENSIONS

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CHAPTER I: THEORETICAL BACKGROUND

Emotion regulation consists of the processes by which individuals influence which emotions they have, when they have them and how they experience and express these emotions (Gross, 1998a, 1998b). Building on the foundations of the modal model of emotion, Gross (1998a) proposed a conceptual framework called the process model of emotion regulation, which argues that each step of the sequence generating an emotion is an opportunity for regulating that response. The resulting model includes five families of emotion regulation processes: situation selection, situation modification, attentional deployment, cognitive change and response modulation.

Integrating knowledge gained from over 15 years of research on emotion regulation, Gross (2015) recently introduced an extended process model of emotion regulation, centered on the notion of valuation systems. Three different stages of the emotion regulation cycle are differentiated: (a) identification - emotion regulation goals are formed; (b) selection - specific emotion regulation strategies are chosen ; (c) implementation - course of action to modify the emotion.

Individual differences in emotion regulation explore the systematic and consistent variation in how individuals regulate their emotional responses. Traditionally, individual differences in emotion regulation were assessed in terms of variation in the habitual use of strategies in everyday life. Investigations deriving from this approach answer questions such as “What makes some individuals use a particular strategy more that others?” or “What are the consequences for individuals who use this strategy more than others?”. The most widely used measure is the Emotion Regulation Questionnaire (ERQ) developed by James Gross and Oliver John in 2003.

In the recent years, experimental studies have shifted towards within-subject designs aimed at investigating individual differences in the ability to regulate emotional responses. Using experimental tasks, researchers try to answer questions such as “What makes some individuals more efficient in using this strategy that others?” or “What are the consequences for individuals who use this strategy more efficient than others?” .

The main focus of the present thesis was to investigate psychological and biological dimensions of individual differences in emotion regulation. We sought to integrate the classic approach looking at individual differences in strategy use with more recent approaches, focusing on individual differences in the ability to use emotion regulation strategies. This double perspective presented the opportunity to (1) gather additional evidence regarding the construct validity of the recently proposed concept of emotion regulation ability; (2) further

explore how it relates to well-validated measures of habitual use; (3) compare their predictive value for various outcomes.

To refine our approach, we further differentiated individual differences in the use of emotion regulation strategies in two categories: habitual use and situational use. We also made a distinction between individual differences in emotion regulation ability by considering actual performance in modulating emotional responses, as well as the self-efficacy beliefs.

As regards the psychological dimensions investigated in the present thesis they include: (1) childhood trauma as an environmental factor which may influence reappraisal ability; (2) the role of specific emotions in spontaneous regulation in daily life; (3) associations between individual differences in reappraisal ability and state anxiety during a stressful situation and (4) interactive effects of personality and emotion regulation, with implications for psychopathology. As regards the biological dimensions investigated in the present thesis they include: (1) genetic variation in the *BDNF* gene as moderating the effect of environment on reappraisal ability; (2) the role of serotonin availability in effective emotion regulation; and (3) associations between individual differences in reappraisal ability and cortisol reactivity during a stressful situation.

A major focus the present thesis was on regulatory processes, with an emphasis on cognitive reappraisal. Our extensive approach on cognitive reappraisal included variations in emotional triggers, regulatory goals and implementation tactics. In addition to the special interest on cognitive reappraisal, we aimed to extend our investigation at the same hierarchical level, by taking into account the spontaneous use of various emotion regulation strategies, but also at lower levels, to include differences among discrete emotions arising in diverse situation.

CHAPTER II: RESEARCH OBJECTIVES AND GENERAL METHODOLOGY

Through the present thesis, we aimed to explore individual differences in emotion regulation from a dual perspective: what contributes to this variability and how does it impact on relevant outcomes.

The first goal of our research was to investigate genetic and environmental contributions to individual differences in emotion regulation. To achieve this goal, we conducted a twin study (Study 1) based on data from monozygotic and dizygotic twins registered in the Romanian Twin Registry. Habitual emotion regulation and self-efficacy beliefs were assessed using self-report questionnaires. Genetic and environmental contributions were estimated using structural equations.

Our second aim was to investigate the role of specific genetic and environmental factors on emotion regulation. To address this aim we conducted a gene-environment interaction study (Study 2), examining the interactive effects of a polymorphism in the brain-derived neurotrophic factor (*BDNF* Val66Met) and childhood stressful events on reappraisal ability. Genotyping was performed using DNA extracted from buccal epithelial cells. A self-report measure of childhood stressful events was used to examine experiences of abuse, loss, illness and parental conflict. Reappraisal ability was measured using an experimental task. Multiple regression analysis was used to test the GxE interaction.

Our third goal was to explore the neurochemical mechanisms of emotion regulation. To this end, we developed an experimental study (Study 3) which used the acute tryptophan depletion procedure, a non-invasive pharmacological manipulation known to reduce tryptophan availability through dietary changes. The efficiency of using reappraisal according to emotion regulation goals (i.e., up-regulation and down-regulation ability) was assessed in an experimental task based on self-reported emotional arousal and physiological indices. Repeated-measures analyses of variance were used to investigate effects of the treatment and emotion regulation instruction on subjective and physiological affective responses.

The fourth objective was to investigate the impact of emotion regulation efficiency, namely reappraisal ability, on stress reactivity (Study 4). During the course of the semester, students attended a laboratory session assesing reappraisal ability. Stress reactivity was assessed outside the laboratory, during a midterm exam. Multiple regression analysis was used to test the effect of emotion regulation on stress reactivity.

Our fifth aim was to investigate relations between the habitual and situational use of emotion regulation and their effects on stress reactivity, in a naturally occurring stressful situation. To accomplish this objective, we conducted an experience-sampling study (Study

5), which allowed us to collect data on the habitual use of emotion regulation in daily life. To assess the situational use of emotion regulation, participants reported the spontaneous use of strategies in a naturally occuring stressful situation, before an exam. Stress reactivity was indicated by subjective reports of emotional arousal as well as a physiological marker, cortisol reactivity. Correlation analysis was used to investigate associations between habitual and situational emotion regulation, as well as between the two measures of emotion regulation and stress reactivity.

Finally, our sixth goal was to investigate whether individual differences in the frequency and efficieny of using reappraisal moderate the impact of personality traits on emotional symptoms (Study 6). Structural equation modeling was used to investigate multiple relationships between dependent and independent variables in the same model.

CHAPTER III: ORIGINAL RESEARCH

3.1 Genetic and environmental contributions to emotion regulation: preliminary findings from the Romanian Twin Registry (Study 1)

Introduction

Twin studies represent the most common approach used to quantify the relative contributions of genetic and environmental factors to individual differences in cognition, emotion or behavior. Comparing the phenotypic similarity of monozygotic (MZ) and dizygotic twins (DZ) allows to partition the observed variance of a trait into genetic (additive or dominant) and environmental factors (shared or non-shared).

Studies investigating genetic and environmental influences on trait-like measures of emotion regulation (Vernon, Petrides, Bratko, & Schermer, 2008) indicated that genetic and non-shared environmental factors significantly contribute to individual differences in facets of trait emotional intelligence (EI). Results from McRae et al. (2017) indicated individual differences in the use of reappraisal to be largely attributable to non-shared environmental factors and to a lesser extent to genetic factors ($a^2 = .20$, $e^2 = .80$), as compared to suppression ($a^2 = .32$, $e^2 = .65$). As individuals differ in their tendencies to use emotion regulation strategies in daily life, they also differ in their beliefs about their ability to control emotional responses. Results from twin studies have pointed toward larger contributions of genetic factors for measures of general self-efficacy, as compared to specific ones.

The purpose of the present twin study is twofold: (1) to investigate genetic and environmental contributions to individual differences in the habitual use of reappraisal and suppression; (2) to examine, for the first time, the extent of genetic and environmental influences on self-efficacy beliefs of using reappraisal and suppression.

Methods

Participants

For the present study, analysis were conducted on 125 twin pairs from the Romanian Twin Registry who provided complete data for the habitual measures of emotion regulation (69 MZ; 56 DZ) and a subset of 119 twin pairs with complete data on self-efficacy measures of emotion regulation (67 MZ, 52 DZ). Mean age of the sample was 21.73 years (SD = 2.82), ranging between 16 and 51 years old.

Measures

Twin zygosity was determined using the zygosity questionnaire from the Danish Twin Registry (Christiansen et al., 2003).

The Romanian version of the Emotion Regulation Questionnaire (*ERQ*, Gross & John, 2003) was used to assess the habitual use of emotion regulation strategies.

A modified form of the *ERQ* (*ERQ Self-efficacy*) was used to assess the perceived self-efficacy of using reappraisal and suppression.

Procedure

Following the registration of both twins, the pair was invited to participate in a baseline assessment of general psychological characteristics. Data was collected through online questionnaires and for confidentiality purposes, twins used unique identification codes.

Statistical analyses

For our main analyses, the relative contributions of genetic and environmental factors were assessed from variance-covariance matrices using structural equation modeling (Falconer, 1989; for a detailed explanation see Purcell, 2013). Using this approach, genetic and environmental factors were modeled as latent variables (A, C, D, E) which were then estimated based on the total observed variance of a particular phenotype.

Results

Main analysis

Eight biometric models with different combinations of latent factors were fitted to the reappraisal and suppression data. The significance of each latent factor (A, D, C & E) was tested by comparing the full ACE and ADE models to restrained models in which the investigated parameters were set to zero.

Based on minimizing the AIC and parsimony, the AE model was chosen as optimal fit for both habitual use and self-efficay beliefs of reappraisal and suppression.

Results (Table 3.1) indicated that genetic and environmental factors have equal and similar contributions to variability in the habitual use of reappraisal (a^2 = .42, e^2 = .58) and suppression (a^2 = .44, e^2 = .56). Furthermore, the resulting estimates indicated reappraisal self-efficacy to be less heritable and more influenced by non-shared environmental factors (a^2 = .37, e^2 = .63) than suppression self-efficacy (a^2 = .52, e^2 = .48).

Table 3.1

Variance components for emotion regulation measures

Emotion regulation measures	r_{MZ}	r_{DZ}	a^2(CI)	c^2(CI)	e^2 (CI)
Habitual Reappraisal	.46	.19	.42 (.23 - .57)	---	.58 (.43 - .77)
Habitual Suppression	.44	.22	.44 (.25 - .58)	---	.56 (.41 - .74)
Reappraisal self-efficacy	0.37	0.24	.37 (.18 - .54)		.63 (.46 - .82)
Suppression self-efficacy	0.58	0.12	.52 (.35 - .65)	---	.48 (.34 - .65)

Note: [a] r_{MZ}= correlation coefficient for monozygotic twins; r_{DZ}= correlation coefficient for dizygotic twins; a^2 = additive genetic variance (narrow sense heritability); c^2= common environmental variance; e^2= specific environmental variance; CI = confidence intervals

[b] Variance estimates based on the best fitting model

Discussion

Results from our sample indicated similar genetic and environmental influences for habitual reappraisal and suppression. This is at odds with the results of McRae et al. (2017), which indicated reappraisal to be less heritable and influenced more by non-shared environment than suppression. Given that contributions of non-shared environment increase with age, this might explain why in our younger sample we obtained estimates of non-shared influences smaller than those reported in older samples (McRae et al., 2017). Furthermore, the estimates from biometrical models vary within a certain range (Johnson, Turkheimer, Gottesman, & Bouchard Jr, 2009), which makes the discrepancy less problematic.

Our results on emotion regulation self-efficacy indicate that, variation in environmental factors, such as the availability of alternative interpretations from others, largely contributes to developing self-efficacy beliefs about the capability of finding new meanings.

Despite the methodological and conceptual advancements, the present study has some limitations. The size of our sample, while acceptable to qualify the results as preliminary

findings, is relatively small compared to those from well-established twin registries. Second, while the psychometric properties of both our measures were satisfactory, we acknowledge potential biases inherent to self-report measures.

In conclusion, the present study explored for the first time the relative contributions of genetic and environmental factors to emotion regulation self-efficacy. Results indicated reappraisal self-efficacy to be less heritable and more influenced by non-shared environment than suppression self-efficacy. In addition, our findings suggest that, similar to other complex quantitative traits, genetic and non-shared environmental factors make significant and relatively equal contributions to the habitual use of reappraisal and suppression.

3.2. Childhood trauma and emotion regulation: the moderator role of *BDNF* Val66Met (Study 2)[1]

Introduction

An increasing number of studies have started to investigate gene-environment interactions (G×E) that may contribute to emotion regulation (for review see Canli, Ferri, & Duman, 2009). One of the candidate genes that have been examined in relation to emotion regulation is the brain-derived neurotrophic factor (*BDNF*). This gene is widely expressed in the brain and its product molecule plays an important role in neuron survival and neuroplasticity (Lu, Pang, & Woo, 2005).

Genetic studies have investigated whether functional polymorphisms such as *BDNF* Val66Met (rs6265) are associated with psychopathology. Using self-report measures of emotion regulation, it was found that *BDNF* Met carriers tend to use less efficient, emotion- rather than problem-focused strategies (Aizawa et al., 2015) and also display an increased tendency to ruminate (Clasen, Wells, Knopik, McGeary, & Beevers, 2011). Importantly, the highest levels of habitual rumination have been found in *BDNF* Met carriers with a history of more stressful events (Clasen et al., 2011) which underscores the moderator role of this polymorphism in the relation between stress and emotion regulation.

Using a cognitive task, Miu et al. (2017a) have recently reported for the first time that reappraisal ability is reduced in *BDNF* Met carriers with a history of child maltreatment. Provided that it is replicated, this result may have implications for understanding G×E interactions that influence emotion regulation and may contribute both to vulnerability for psychopathology, and response to psychotherapy.

The present study was designed to replicate and extend, in an independent sample, the previous *BDNF* Val66Met × childhood stressful events in emotion regulation. In addition to child maltreatment, other types of childhood trauma were also assessed in order to explore the extent of this effect.

Methods

Participants

[1] Study 2 was published as an original study:
Bîlc, M. I., Vulturar, R., Chiș, A., Buciuman, M., Nuţu, D., Bunea,I., . . . Miu, A. C. (2018). Childhood trauma and emotion regulation: The moderator role of BDNF Val66Met. *Neuroscience letters, 685*, 7-11.

Two hundred and sixty-six volunteers (218 women), aged 18 to 44 (M = 20.57, SD = 3.76 years), participated in this study.

Measures

Genotyping. DNA was extracted from buccal epithelial cells. *BDNF* Val66Met genotyping was performed as previously described (Miu et al., 2017a).

Childhood trauma. The Childhood Traumatic Events Scale (Pennebaker & Susman, 1988) was used to investigate the history of traumatic events before age 17.

Reappraisal ability. Reappraisal ability was assessed using a computerized cognitive task. Participants were presented with emotionally neutral and negative images which they either attended or reappraised in order to decrease their emotional impact Reappraisal ability was estimated as the mean decrease in negative affect when using reappraisal relative to passive looking (Ochsner, 2004) such that higher scores indicated greater reappraisal ability or decreases in negative affect due to reappraisal.

Statistical analysis

The G×E interaction was tested using multiple regression analysis. To control for the potential confounding effect of sex, both sex and its interactions with genotype and childhood trauma were entered in the regression model (Keller, 2014).

Results

Results of the multiple regression indicated a negative relation between sex and reappraisal ability, with increased performance in women (β = -0.182, p = .003). While neither *BDNF* Val66Met (β = 0.098, p = .106), nor childhood trauma (β = 0.005, p = .933) had a significant effect, their interaction was a significant predictor of reappraisal ability (β = 0.213, p = .013). Slope analysis indicated a significant negative association between childhood trauma and reappraisal ability in BDNF Met carriers, but not Val homozygotes.

Discussion

Results of the present study indicate that *BDNF* Val66Met is a moderator in the relation between childhood trauma and reappraisal ability, replicating our previous findings (Miu et al., 2017a). Here, as well as in previous research (McLaughlin, Peverill, Gold, Alves, & Sheridan, 2015; Miu et al., 2017a) only *BDNF* Met carriers with a history of childhood trauma showed poor reappraisal efficiency. This may be explained by the distal influence of childhood trauma, which may contribute to emotional problems when acting in tandem with

genetic factors (Hammen, Henry, & Daley, 2000; McLaughlin, Conron, Koenen, & Gilman, 2010).

Although *BDNF* Met carriers may be at risk following early stress, they may also show the highest sensitivity to interventions targeting reappraisal, such as cognitive-behavioral psychotherapy (Goldin et al., 2012). Further research on *BDNF*Val66Met as a "plasticity gene" (Belsky et al., 2009) involved in the response to psychotherapeutic interventions (Lester & Eley, 2013) is warranted in the future.

We acknowledge that the sample size in this study is not ideal for detecting the typically small effects of genetic polymorphisms. However, having used a performance-based measure of emotion regulation, which is more time consuming than self-report questionnaires, precluded us from of recruiting a larger sample in this study. In defense of the present results, we argue that the *BDNF* Val66Met × childhood trauma was replicated in two independent samples (Miu et al., 2017a; the present study) and showed considerable statistical robustness given that different measures of childhood stressful events and different sets of affective stimuli were employed in the two studies.

In conclusion, the present results suggest that *BDNF* Met carriers may be particularly vulnerable to childhood trauma, showing a dose-response effect of the number of early stressful events on emotion regulation efficiency.

3.3 Role of serotonin in emotion regulation: an acute tryptophan depletion study (Study 3)

Introduction

Serotonin is known to have a central role in mood regulation and affective disorders. Given that serotonin synthesis is directly dependent on the availability of its precursor, tryptophan (TRP), experimental procedures use dietary manipulations to alter tryptophan levels and to study its effects on mood and cognition.

Acute tryptophan depletion (ATP) is an experimental procedure causing a substantial, but easily reversible reduction in plasma tryptophan (Young, Smith, Pihl, & Ervin, 1985). This effect is obtained by the ingestion of a mixture which contains multiple large neutral amino-acids (LNAAs), but lacks tryptophan.

Despite extensive evidence supporting the role of serotonin in modulating emotional states (Evers, Sambeth, Ramaekers, Riedel, & Van der Veen, 2010; Raab, Kirsch, & Mier, 2016), to the best of our knowledge, no studies have investigated the effects of acute tryptophan depletion on emotion regulation. One particular index of physiological responses emerged as a reliable marker of regulated emotional responding: heart rate variability (HRV, Appelhans & Luecken, 2006). Studies examining heart rate variability during active emotion regulation tasks have shown that various HRV measures were associated with the use worry (Aldao, Mennin, & McLaughlin, 2013; HRV composite score), reappraisal (Di Simplicio et al., 2012; HF-HRV) and acceptance (Wang et al., 2016; LF/HF ratio).

The aim of the current study was to investigate the effects of ATD during an emotion regulation task. Specifically, we examined whether: (1) the ATD procedure had an effect on self-reported negative affect and heart rate variability during the emotion regulation task; (2) the effect of ATD varied as a function of individual differences in habitual emotion regulation and trait anger.

Methods

Participants

Twenty-eight male participants, aged 18 - 35 years (M = 21.96, SD = 4.58) were included in this study. Exclusion criteria included past or current physical health problems.

Acute tryptophan depletion

The ATD procedure involved the ingestion of an amino acid load that specifically lacks L-tryptophan (TRP). The placebo condition involved the ingestion of an amino acid mixture with a balanced (BAL) proportion of tryptophan.

Emotion regulation task

On each experimental condition, participants underwent an emotion regulation task. They were presented with short movie clips and required to: (1) naturally attend to the films (Look); (2) try to reappraise the movie content in order to decrease their emotional responses (Decrease); (3) try to reappraise the movie content in order to increase their emotional responses (Increase).

Measures

Screening measures

Participants reported lifetime history of chronic, neurological, endocrine and psychiatric health problems, as well as current medication. The screening module of the Structured Clinical Interview for DSM-IV (First, Spitzer, Gibbon, & Williams, 2002) was included to check for mental health issues.

A*mino acids*

Venous blood samples (5 ml taken in EDTA tubes) were analysed to determine the total plasma tryptophan level and the ratio of tryptophan to other large neutral amino acids (TRP:ΣLNAA ratio).

Affect

The Positive and Negative Affect Schedules (*PANAS*, Watson & Clark, 1999) is a self-report measure used to assess participants' mood before and 5½ hours after the ingestion of amino acids mixture.

The Discrete Emotions Questionnaire (*DEQ*, Harmon-Jones, Bastian, & Harmon-Jones, 2016) is a self-report measure used to assess participants' emotional responses after each movie clip.

Heart rate variability (HVR)

ECG recordings were obtained using a Biopac MP150 system (Biopac Systems, CA, USA). HRV analyses were conducted for the baseline recordings and for each segment of movie presentation using: mean R-R interval/inter-beat interval (IBI, ms); LF and HF power (ms^2), as well as the LF/HF ratio.

Individual differences

The Emotion Regulation Questionnaire (*ERQ*, Gross & John, 2003) was used to assess individual differences in the habitual use of reappraisal.

The State-Trait Anger Expression Inventory (*STAXI*, Spielberger, 1988) was used to assess trait anger.

Procedure

The study had a double-blind, repeated measures crossover design. The two lab visits lasted aproximately 8 hours including: (1) fill-in PANAS I and draw first blood sample; (2) drink amino acids mixture: (3) wait 5½ hours; (4) fill-in PANAS II and draw second blood sample; (5) emotion regulation task.; (6) administer 1g TRP/placebo.

Statistical analyses

Repeated measures ANOVA with treatment and instruction type as within subject factors was used to investigate differences in negative affect ratings and HRV during the emotion regulation task.

Paired samples t-tests were used to investigate differences in reactivity, down-regulating and up-regulating reappraisal ability as a function of treatment condition (tryptophan depletion vs. placebo).

Multiple regression analysis was used to investigate the relation between treatment effects and individual differences in the habitual use of reappraisal and trait anger.

Results

Subjective reports

Results of the repeated measures ANOVA indicated a significant main effect of instruction ($F[2.36, 63.83] = 56.208$, $p < 0.001$) on negative affect ratings for movie clips. The effect of treatment ($F[1, 27] = 0.915$, $p = 0.347$) and the interaction effect ($F[2.19, 59.20] = 0.443$, $p = 0.662$) were not significant. Post-hoc test indicate that irrespective of the treatment condition, use of reappraisal was successful in decreasing scădea ($M = 10.00$, $SD = 0.82$) and increasing negative affect ($M = 13.81$, $SD = 0.874$) compared to the control condition ($M = 11.25$, $SD = 0.81$). Negative affect was lowest during the neutral film presentation ($M = 5.92$, $SD = 0.37$).

Paired sample t-tests indicated no significant differences in reactivity ($t[27] = 0.682$, $p = 0.501$, down-regulating ability ($t[27] = -0.375$, $p = 0.710$) and up-regulating ability ($t[27] = -0.412$, $p = 0.683$) as a function of treatment condition.

Results of the multiple regression analyses indicated a marginally significant effect of individual difference on down-regulating reappraisal ability ($F[2, 25] = 2.930$, $p = 0.074$).

More specifically, higher habitual reappraisal (β = 0.388, p = 0.050), but not trait anger (β = 0.286, p = 0.141), predicted greater decreases in negative affect in the tryptophan depletion condition relative to placebo. Effects were not significant for up-regulating reappraisal ability and reactivity scores.

Heart rate variability (HRV)

Results of the repeated measures ANOVA indicated a significant main effect of instruction on the inter-beat interval (F[3, 69] = 10.506, p < 0.001). The effect of treatment (F[1, 23] = 0.016, p = 0.901) and the interaction effect (F[3, 69] = 0.259, p = 0.855) were not significant. Post-hoc tests indicated greater reduction from baseline during Increase (M = -53.70, SD = 9.79) compared to Look negative (M = -18.35, SD = 8.59). Remaining comparisons were only marginally significant.

Results of the repeated measures ANOVA indicated no significant effects of treatment, instruction, or their interaction on LF and HF power, respectively. However, results on the LF/HF ratio indicated a significant interaction effect (F[3, 69] = 3.312, p = 0.025. Follow up simple slopes analysis revealed that LF/HF ratio was significantly higher in the ATD compared to placebo conditions, only when increasing negative affect (t[24] = 2.42, p = 0.023). No significant differences were found during the orther conditions of the emotion regulation task.

Discussion

The present study investigated the effects of acute tryptophan depletion, an experimental procedure known to decrease serotonin synthesis in the brain, on the ability to regulate emotional responses according to goals.

Results on the subjective reports during the emotion regulation task indicated that use of reappraisal was effective in modulating emotional responses according to goals and that the effect of ATD might be influenced by individual differences in the habitual use of reappraisal. To our knowledge, this is the first study to provide evidence for coordinated changes in heart rate variability according to emotion regulation goals. In addition, our results suggest that, effects of tryptophan depletion, although not reflected in self-reported arousal, can be assessed based on physiological reactivity.

To the best of our knowledge, this is the first study to explore effects of ATD on emotion regulation. Using of a well-validated emotion regulation task alongside reliable physiological indices increased the reliability of our results. However, as our analyses reflect, the study

may have been partially underpowered to detect significant effects (e.g., observed power for change in mood was $1-\beta = 0.47$). The high costs of the aminoacids used in the tryptophan depletion procedure constrained us from extending our sample.

To conclude, our results indicate that overall, acute tryptophan depletion showed no effect on self-reported negative affect during an emotion regulation task. However, indices of physiological reactivity, such as HRV, might be better able to capture effects of tryptophan depletion which are not evident in self-reported arousal. Future research is needed to replicate these preliminary findings and to extend the investigation in samples of female participants as well as in clinical samples.

3.4 Reappraisal ability and anxiety before exam (Study 4)

Introduction

A recent meta-analyis (Webb, Miles, & Sheeran, 2012) has supported the view that cognitive reappraisal modulates emotional experience more efficiently than other cognitive strategies. As reappraisal allows one to attend to the event, while reinterpreting it (Sheppes, Scheibe, Suri, & Gross, 2011) is particularly useful when one has to attend to events that are, for instance, part of one's occupation. Moreover, the benefits of reappraisal in controlling emotional responses to an event are retained at subsequent exposures to similar situations (Denny, Inhoff, Zerubavel, Davachi, & Ochsner, 2015; Denny & Ochsner, 2014), which highlights the long-term advantages of using this emotion regulation strategy.

Until recently, studies have mostly focused on the habitual use of reappraisal, assessed using questionnaires (Gross & John, 2003). Using laboratory tasks in which participants are presented with affective stimuli (i.e., images) and report the success of controlling emotional responses using reappraisal, it has been found that reappraisal ability does not overlap with habitual reappraisal (McRae, 2013; McRae, Jacobs, Ray, John, & Gross, 2012; Troy, Wilhelm, Shallcross, & Mauss, 2010). Moreover, reappraisal ability may better capture the moderating role of this emotion regulation strategy in the relation between stressful life events and depressive symptoms, above and beyond habitual reappraisal (Troy et al., 2010).

The present study investigated for the first time the relation between reappraisal ability assessed using a laboratory task and anxiety before an exam in students. Reappraisal may be extremely useful during exams considering that students must attend to these situations, while also regulating their emotions in order to prevent them from altering performance. Therefore, we examined the hypothesis that students with higher levels of reappraisal ability would show reduced anxiety before an exam.

Methods

Participants

One hundred and four students (86 women), aged 19 to 24 (M = 19.51, SD = 1.07 years) participated in this study. From this initial sample, N = 92 participants completed both the laboratory assessment and the exam measure.

Measures

Reappraisal ability task. Reappraisal ability was estimated as the percent decrease in mean emotional arousal when using reappraisal, compared to mean emotional arousal when

reacting naturally to negative pictures. Positive scores indicate decreases in emotional arousal due to reappraisal and higher scores represent higher reappraisal ability.

Habitual reappraisal. The Emotion Regulation Questionnaire (ERQ, Gross & John, 2003) is designed to assess individual differences in the habitual use of cognitive reappraisal and expressive suppression.

State anxiety. State-Trait Anxiety Inventory (STAI-S, Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) has 20 items (e.g., "I am tense") to assess state anxiety.

Procedure

During the course of the semester, participants filled in online demographic data and the ERQ-Reappraisal. They were then scheduled for a lab session of about 30 minutes to undergo the reappraisal ability task. Participants were informed that the second part of the study will take place on a designated exam day. Thirty minutes before the exam, they filled in STAI-S and rated how important the exam was for them and how difficult they expected it to be.

Statistical analysis

A hierarchical multiple regression analysis was conducted with STAI-S state anxiety as the outcome and sex (0 = male, 1 = female), importance and difficulty evaluations of the exam, habitual use of reappraisal and reappraisal ability as predictors.

Results

Results of the hierarchical regression analysis revealed that sex was a significant predictor ($\beta = 0.24$, $p = .020$), accounting for 5% of the variance in state anxiety before exam. Evaluations on the importance ($\beta = 0.19$, $p = .031$) and difficulty of the exam ($\beta = 0.44$, $p = .001$) were also significant predictors, accounting for 22% of the variance in state anxiety before the exam. Whereas habitual reappraisal was not a significant predictor ($\beta = -0.01$, $p = .852$), reappraisal ability ($\beta = -0.19$, $p = .050$) explained an additional 3% of variation in state anxiety before exam. As expected, higher reappraisal ability predicted lower state anxiety before exam.

Discussion

The results of the present study supported the hypothesis that reappraisal ability is negatively associated with state anxiety before an exam. These results extend previous findings on the role of reappraisal ability in stress regulation and illustrate the potential of linking performance-based measures of emotion regulation and field measures of emotion.

Importantly, the association between reappraisal ability and state anxiety before exam was independent of both individual differences in appraisals of exam difficulty and importance, and sex differences. However, the effect of reappraisal was small and we believe that several factors may account for this. First, the present study did not assess whether participants employed reappraisal in regulating anxiety before exam. This may have contributed to an underestimation of the contribution of individual differences in reappraisal ability. Second, stress levels associated with the mid-term exam may have been too high for reappraisal to work. Previous evidence suggested that reappraisal efficiency is reduced when emotions are very intense (Sheppes & Meiran, 2008) and that other strategies, such as distraction, may work better in these conditions. Third, differences between the reappraisal ability assessment and the exam situation may have contributed to the small magnitude of the effect. That is, reappraisal ability was assessed in a task with images and the exam situation may have triggered anxiety through other modalities (e.g., thoughts).

Despite limitations, we believe that our results hold promising implications for interventions aimed at improving emotion regulation abilities to reduce anxiety in educational contexts. Reappraisal might be particularly useful in these contexts considering that its efficient use in one situation can benefit emotional responses at subsequent exposures to similar situations (Denny et al., 2015). Students are required to face many exams and reappraisal ability may be instrumental in regulating emotional responses and preventing them from interfering with performance across situations.

In conclusion, the present results support the link between individual differences in reappraisal ability and anxiety. Moreover, they show that reappraisal ability does not overlap with habitual reappraisal, and suggest that the former measure may better capture the active role of this emotion regulation strategy in acute stress.

3.5 Emotion regulation and exam stress: an experience sampling study (Study 5)

Introduction

Recent approaches underscore the role that contextual factors play in the emotion regulation process (Aldao, 2013; Bonanno & Burton, 2013). Experience sampling methods (ESM) might be particularly suitable for this goal, as they as they capture a greater variety of emotional and situational contexts. ESM also offer a promising approach to studying individual differences in emotion regulation. Momentary assessments of emotion regulation in multiple situations and emotions can be aggregated at the individual level to indicate typical use of strategies in daily life.

As efficient emotion regulation was shown to contribute extensively to managing stressful situations (Jamieson, Mendes, & Nock, 2013; Troy, Shallcross, & Mauss, 2013; Troy et al., 2010), researchers began investigating the effects of emotion regulation on biomarkers of emotional responses, such as cortisol. Results from such studies show that, at times, effects of spontaneous emotion regulation are shown to differ from those reported using habitual measures (de Veld, Riksen-Walraven, & de Weerth, 2012; Zoccola, Dickerson, & Zaldivar, 2008; Zoccola, Quas, & Yim, 2010). The use of dispositional indices of emotion regulation, as derived from experience sampling methods, might help clarify these inconsistencies and allow the exploration of a larger set of regulation strategies.

The aims of the present study were to investigate: (1) how different emotions relate to the use of different emotion regulation strategies in daily life; (2) how the frequency of using strategies in daily life, as derived from experience sampling methods, is connected to their use in a specific exam situation; (3) how the use of emotion regulation both in daily life and at the exam is associated with cortisol levels and state anxiety at the exam.

Methods

Participants

Eighty-nine students (75 women), aged 19 to 22 (M = 19.69, SD = 0.69 years) participated in this study. Out of this initial sample, N = 74 (63 women) completed both the experience sampling measures and the exam measures.

Measures

Experience sampling

In this study, the app prompted participants 3 times per day, for ten consecutive days, asking them to report their emotional experience, the related situations, and the use of emotion regulation strategies.

Exam measures

The State-Trait Anxiety Inventory (STAI-S, Spielberger et al., 1983) is a self-report measure of state anxiety. Emotion regulation at the exam was investigated using the corresponding items from the experience sampling questionnaire. Cortisol was assayed from saliva samples .

Procedure

Experience sampling measures took place during the course of the semester. The second part of the study took place on a designated exam day. Saliva samples were collected before (-30 min and -15 min), during (+20 min) and after the exam (+90 min). In addition, at -15 min, participants also filled in the STAI-S and reported on the spontaneous use of emotion regulation strategies.

Statistical analyses

Pearson chi-square tests of independence were performed to compare the frequency of using each emotion regulation strategy among different emotions.

To investigate association between emotion regulation in daily life and exam measures (i.e., emotion regulation, cortisol and anxiety) we first aggregated ESM data for each individual as follows: (reports of using strategy / total reports) × 100. For variables where sex differences were significant, nonparametric partial correlations were used to control for the effect of sex.

Results

Emotions and emotion regulation in daily life

Emotion regulation strategies such as distraction, non-acceptance, situation modification, suppresion and reappraisal were more likely to be used for regulating negative emotions and less likely for positive emotions. Savoring and future positive showed the opposite pattern. Participants selectively used rumination when experiencing sadness compared to other emotions. Self-blaming was more likely to be used for regulating anxiety, shame, guilt and less likely for anger. Others blaming was more likely used in regulating anger, but also joy and surprise, and less likely for anxiety.

Emotion regulation in daily life and emotion regulation at exam

As expected, daily use of some strategies (i.e., suppression, rumination, future positive and self-blaming) was related to their use at the exam. In addition, several emotion regulation

strategies used in daily life were related to other emotion regulation strategies at the exam (e.g., situation modification - suppression; self-blaming in daily life - rumination at the exam).

Relations between emotion regulation in daily life and exam stress

Higher use of distraction (r = 0.24), others blaming (r = 0.30), and nonacceptance (r = 0.24), in daily life were associated with increased cortisol AUC_G at exam, after controlling for the effect of sex. In addition, levels of rumination in daily life were marginally associated with both cortisol AUC_G ($p = 0.051$) and state anxiety ($p = 0.050$) at exam.

Relations between emotion regulation at the exam and exam stress

Those who reported using situation modification at the exam displayed lower cortisol compared to those who did not report using this strategy (t[45.37] = -2.38, $p = 0.021$, $d = 0.54$). However, state anxiety was higher in the former (t[71] = 2.11, $p = .038$, $d = 0.49$). State anxiety was also significantly higher in those who reported using rumination (t[71] = 4.95, $p < 0.001$, $d = 1.20$) and non-acceptance (t[57.82] = 4.37, $p < 0.001$, $d = 1.03$) at the exam, compared to those who did not use these strategies. No significant differences were found for the remaining strategies.

Discussion

The present study used ESM to assess emotion regulation in daily life in a sample of young adults. This provided the opportunity to sample a wide range of emotional experiences in multiple situations, while reducing memory biases.

Our study holds several strengths and limitations that offer directions for future research. The use of experience sampling measures allows increased the generalizability of the our results. Second, we assessed situational use of emotion regulation and stress reactivity in a specific, real-life context, which increases the ecological validity of the results. Third, the consistency of emotion regulation measures allowed us to capture associations between tendencies of using strategies in daily life and their specific situational use. Fourth, evaluating stress reactivity in terms of biological responses and subjective experiences granted us a more complex picture of how various aspects of stress responses are related to emotion regulation. Nevertheless, our results on the effects of emotion regulation on stress reactivity are limited by the general examination of strategy use. As previous studies have suggested, when evaluating a strategy's overall effect, successful and unsuccessful attempts might cancel each

other, thus limiting the interpretation of its effects. Future studies could collect data regarding participants' self-reported efficiency of using each emotion regulation strategy.

To conclude, the current study provides valuable insight in use of emotion regulation in daily life. Specifically, our results indicate that people's emotion regulation attempts depend on the specific emotion they experience. Second, individuals show consistency between patterns of emotion regulation in daily life and behavior in a specific acute stres situation. Third, biological responses to stress relate more to patterns of regulation in daily life, while the emotional experience in a stressful situation was more sensitive to the actual emotion regulation behavior.

3.6 Emotion regulation as moderator in the relationship between personality and psychopathology (Study 6)

Introduction

Independent lines of evidence show consistent links between individual differences in personality traits, emotion regulation and psychopathology. Neuroticism emerged as the strongest predictor (Kotov, Gamez, Schmidt, & Watson, 2010) with positive associations across all disorders. While low extraversion also characterised the profiles of all disorders, effects were relatively smaller compared to neuroticism, particularly strong for dysthimia and social phobia. High use of reappraisal in daily life was associated with low levels of depression (Garnefski & Kraaij, 2006; Garnefski, Teerds, Kraaij, Legerstee, & van Den Kommer, 2004; Gross & John, 2003), as well as anxiety and stress symptoms (Martin & Dahlen, 2005; Moore, Zoellner, & Mollenholt, 2008). Reappraisal ability was shown to moderate the impact of stressful events, particularly uncontrollable ones, on depression symptoms (Troy et al., 2013; Troy et al., 2010).

However, less is known about the way in which these potential vulnerability and protective factors interact to predict emotional symptoms. Previous studies indicate that the association between neuroticism and depression may partially be explained by the increased use of maladaptive strategies, such as rumination, but not adaptive strategies such as reappraisal (Andrés, Richaud de Minzi, Castañeiras, Canet-Juric, & Rodríguez-Carvajal, 2016; Yoon, Maltby, & Joormann, 2013).

The aim of the present study was to investigate the moderating effects of emotion regulation on the relationships between personality traits and emotional symptoms. Specifically, we sought to investigate whether (1) individual differences in the dispositional use of reappraisal would moderate the impact of personality traits on depression, anxiety and stress-related symptoms; (2) individual differences in the efficiency of using reappraisal would moderate the impact of personality traits on depression, anxiety and stress-related symptoms.

Methods

Participants

Two hundred eighy-five students (N = 285, 83.15% women) participated in this study. Mean age of the sample was 20.61 years (SD = 4.58), ranging between 18 and 47.

Measures

Personality. The Romanian version of the Big Five Inventory was used to assess personality traits, as reflected in the "Big Five" model (BFI, John & Srivastava, 1999).

Emotion regulation. The habitual use of reappraisal was assessed using the Romanian version of the Emotion Regulation Questionnaire (Gross & John, 2003).

Reappraisal ability scores represent the difference in emotional arousal between reacting naturally to negative pictures and reappraising them to decrease their emotional impact. Higher scores indicate higher reappraisal ability.

Emotional symptoms. Depression, anxiety and stress symptoms were assessed using the Romanian version of the Depression Anxiety Stress Scales (Lovibond & Lovibond, 1995; DASS- R 21, Perte & Miclea, 2011).

Procedure

Participants attended an individual lab session of about one hour. Self-report questionnaires were filled-in at the beginning of the session. After a short break, participants were required to complete the reappraisal ability task.

Statistical analysis

Relations among personality traits, emotional symptoms and emotion regulation were tested using Structural Equation Modeling (SEM). We used a two-stage analytical approach (Anderson & Gerbing, 1988) which included measurement models first, followed by the structural model. Multi-group analyses were used to investigate the moderating effect of emotion regulation on the relations between personality traits and emotional symptoms.

Results

The structural model included personality traits as exogenous variables and depression, anxiety and stress symptoms as endogenous variables. Results indicated that the model fitted the data very well ($\chi^2 = 414.17$, df = 202, $\chi^2/df = 2.05$, CFI = 0.941, RMSEA = 0.061 [0.052, 0.069]). Extraversion was negatively associated with depression symptoms, whereas neuroticism was positively associated with depression, anxiety and stress symptoms.

Results of the multi-group analysis indicated that the difference in chi-square between the unconstrained model and the model in which regression coefficients were fixed equal was statistically significant ($\Delta\ \chi^2 = 28.74$, $\Delta df = 15$, $p = 0.017$). Higher extraversion was associated with lower depression symptoms in the high habitual reappraisal group ($\beta = -0.215$, $p = 0.044$), but not in the low habitual reappraisal group ($\beta = -0.109$, $p = 0.396$). Neuroticism significantly predicted emotional symptoms in both groups, however the

magnitude of the effect was lower in the high habitual reappraisal group compared to the low habitual reappraisal group.

Results of the multi-group analysis indicated that the difference in chi-square between the unconstrained and the constrained was not statistically significant ($\Delta \chi^2 = 17.45$, $\Delta df = 15$, $p = 0.292$). Therefore, the findings do not provide support for the moderating role of reappraisal ability in the relationships between personality traits and emotional symptoms.

Discussion

The present study sought to investigate the interactive effects of emotion regulation and personality traits on emotional symptoms. It aimed at extending previous studies in two ways: (1) simultaneous modeling of relations among all personality traits in the Big Five model and multiple emotional symptoms (i.e., depression, anxiety and stress); (2) examining the differential effect of habitual and efficiency-based measures of reappraisal.

Results from the structural model indicated that higher extraversion was associated with fewer depression symptoms, but was not related to anxiety and stress symptoms. Additionally, our results indicate that higher neuroticism was associated with more depressive, anxiety and stress-related symptoms.

Results of the multi-group analyses support the role of habitual reappraisal in moderating the effect of personality traits on emotional symptoms. However, the effect of reappraisal ability on emotional symptoms seems to be relatively independent of personality traits. While personality traits interacted with similar trait-like measures of emotion regulation to predict emotional symptoms, it is plausible that other efficiency measures, such as executive functions are better candidates to uncover interactive effects of reappraisal ability.

Several strengths and limitations of the current study warrant attention. Collecting data from a large sample allowed us to use structural equation modeling, thus investigating complex, simultaneous relations among personality traits and emotional outcomes. Use of confirmatory factor analysis granted us high validity and reliability of the investigated constructs. However, the use of cross-sectional measures limits causal interpretations. Future studies could strive to use longitudinal designs to establish causal relations between personality traits and emotional symptoms

In conclusion, the results provide a comprehensive view of the interactive effects of personality traits and emotion regulation in predicting emotional symptoms. Our findings support the role of habitual reappraisal, but not reappraisal ability, in moderating the effect of personality traits on emotional symptoms. Frequent use of reappraisal in daily life was shown

to enhance the protective effect of extraversion and dampen the vulnerability effect associated with neuroticism.

CHAPTER IV: GENERAL CONCLUSIONS AND IMPLICATIONS

4.1 General conclusions

The overarching goal of the present thesis was to explore individual differences in emotion regulation in terms of antecedents to this variability and it's correlated outcomes.

Our findings indicate that genetic and non-shared environmental factors have similar contributions to individual differences in the habitual use of reappraisal and suppression. Furthermore, specific genetic (i.e., the Val66Met polymorphism in the BDNF gene) and environmental factors (i.e., childhood trauma) were shown to have an interactive effect on the efficiency of using reappraisal. In which neurochemical mechanisms are concerned, acute tryptophan depletion showed no effect on self-reported negative affect during an emotion regulation task. However, serotonergic modulation of the ability to decrease negative affect was shown, in our study, to vary as a function of individual differences in the habitual use of reappraisal.

Findings from our studies provide support for the role of emotion regulation in stress reactivity. Habitual use of emotion regulation strategies was associated with biological markers of stress reactivity, whereas the situational use of emotion regulation strategies in the exam situation was related to subjective reports of anxiety. Also, higher efficiency of using reappraisal was related to lower anxiety before an exam. As for the role of emotion regulation in psychopathology our findings indicate that habitual reappraisal, but not reappraisal ability, moderated the effect of personality traits on emotional symptoms.

4.2 Theoretical, practical and methodological implications

Our findings emphasize that individual differences in patterns of strategy use can be reliably conceptualized as trait-like, dispositional qualities. They also provide additional evidence for the conceptual differentiation of habitual and performance-based measures of emotion regulation. Furthermore, they underscore the role of reappraisal ability as an intermediate phenotype that is highly sensitive to G×E interactions.

Result from our twin study suggest that if environmental contributions are highly relevant for reappraisal self-efficacy, than patients might gain valuable input from therapeutic techniques meant to help them be more confident in their capabilities of cognitive restructuring. Findings on the role of reappraisal ability hold promising implications for interventions aimed at improving emotion regulation abilities to reduce anxiety in educational contexts. As our results point out, frequent use of reappraisal in daily life was shown to enhance the beneficial effect of extraversion and dampen the vulnerability associated with

neuroticism. While changes in personality traits are limited, individuals can actively change their patterns of strategy use and turn emotion regulation in their benefit.

Studies included in the present thesis make important contributions to emotion regulation assessment through the use of experience sampling methods and experimental tasks with various emotion inducing stimuli. We also examined stress reactivity outside the laboratory, using subjective reports of emotional arousal as well as reliable biomarkers of stress reactivity.

4.3 Limitations and future directions

The relatively small sample size qualifies the results from some of our studies as preliminary findings. Using a relatively small sample of twin pairs could have increased the measurement error, thus affecting variance estimates of genetic and environmental contributions. As the number of twins joining the Romanian Twin Registry will increase, it is our aim to replicate our findings in a larger sample. Future studies examining the genetic and environmental contributions to performance-based measures of emotion regulation are also needed as they might add further evidence to the ongoing debate between dispositional and ability assessments.

Given the time-consuming and costly procedure of acute tryptophan depletion, we were limited to conduct our investigation in a relatively small, homogeneous, male-only sample. Future studies could test the replicability and generalizability of our findings in other populations.

The other major limitation concerns the generalizability of our results. As most of our samples were drawn from student populations, the data we have gathered is likely to be specific to young, highly educated individuals. Future studies should aim at recruiting more diverse populations, thus also increasing variability in environment sensitive measures.

While assessments of stress reactivity outside the laboratory represents an encouraging step forward, part of our work was limited to an academic context. As we have previously argued, use of reappraisal seems particularly advantageous in this case. However, in other situations use of other strategies might confer additional benefits.

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