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Ph.D. THESIS

COGNITIVE AND EMOTIONAL CORRELATES OF RUMINATION

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CHAPTER I. INTRODUCTION

Rumination is defined as the cognitive process that focus the attention on the symptoms of distress and on the cognitive assessment of causes and consequences of distress (Nolen-Hoeksema et al., 2008). As a maladaptive emotion regulation strategy, rumination plays an important role in psychopathology (i.e., *depression*, Susan Nolen-Hoeksema, 2000). Depressive symptoms have been frequently related to declines in executive functions (*inhibition, attentional control, shifting, working memory*, and *cognitive biases*, e.g., Merriam, Thase, Haas, Keshavan, & Sweeney, 1999). Although depressive symptoms itself may be associated with cognitive deficits, recent perspectives proposed that rumination, that is a risk factor for depressive symptoms, impairs controlling patterns of thinking (e.g., Davis & Nolen-Hoeksema, 2000; Watkins, Teasdale, & Williams, 2000).

Several theoretical accounts have attempted to offer explanations for the relationship between rumination and EFs deficits (i.e., Joormann, 2010; Koster et al., 2011; Whitmer & Gotlib, 2013) suggesting that (a) deficits in inhibiting negative material leads people to ruminate about negative content (Joormann, 2010); (b) people who experience rumination are characterized difficulties in exercising attentional control in response to negative thoughts (Koster et al., 2011).; and (c) negative mood is responsible for ruminative thinking by narrowing the scope of attention and limiting available thoughts, percepts or actions that will be activated in the working memory or available for selection in long term memory (Whitmer and Gotlib, 2013). However, although rumination may be explained by EFs deficits, the exact nature of this relationship remains unclear. A clear causal relationships between rumination and EFs is difficult to be established due to numerous inconsistencies. For instance it is not clear if an actual association between rumination and EFs exists and how strong this association is or training cognitive functions is effective in reducing rumination. Thus, we consider that using a meta-analytical approach would provide a clearer image on the rumination - EFs relation, and could provide answers to current ambiguities in the literature.

Rumination was mainly investigated in relationship with numerous affective disorders (e.g., Papageorgiou & Wells, 2004). Despite of negative emotional consequences of rumination, the cognitive mechanisms (i.e., attentional bias) underlying this disposition are not yet well understood (e.g., Beckwé, Deroost, Koster, De Lissnyder, & De Raedt, 2014). The potential involvement of attentional bias to negative information in rumination was proposed in several theoretical accounts (for reviews see: Koster et al., 2011; Whitmer & Gotlib, 2013). Additionally, it was also suggested that attentional bias to negative information may increase the intensity of state anxiety responses (MacLeod & Mathews, 2012). However, the cognitive mechanisms through which ruminative disposition influences state anxiety are not yet fully understood.

Although, it was also suggested that attentional bias to negative information might be related to ruminative disposition (e.g., Grafton et al., 2016) most studies used trait measures of rumination. Given the instability of trait measures of rumination there is also a need for researches that explore these relationships using state rumination measures.

However, new perspectives postulate that emotion regulation strategies might be impaired be the cognitive depletion (Grillon et al., 2015). After engaging in a demanding cognitive task, cognitive resources of people decrease which can lead to emotion regulation impairments (Grillon et al., 2016). However, this assumption has been empirically tested in few studies, so more studies are needed to investigate these issues. As rumination is considered a maladaptive emotion regulation strategies it is important to explore how cognitive depletion influence state rumination.

When vicious cycle of rumination it is triggered by negative content which became more accessible and it is maintained by cognitive biases (Nolen-Hoeksema et al., 2008). Previous researches on cognitive biases in ruminators focused on attentional and memory biases. However, recently it was suggested that another cognitive bias may be responsible for increasing ruminative thoughts. The way we interpret a situation may influence the ruminative tendency. Furthermore, recent computerized cognitive bias modification (CBM) procedures aimed to modify the interpretation (CBM - I) showed promising results in effectively reducing psychopathology (e.g., Dearing & Gotlib, 2009). Considering the important role of rumination in psychopathology, finding new modalities which can reduce ruminative thoughts, would clearly have numerous practical implications.

This thesis is aimed to address the gaps found in the literature trying to overcome its theoretical and methodological limitations. Furthermore, we have proposed new experimental designs aiming to reduce the number of confounded variables.

CHAPTER II. OBJECTIVES AND GENERAL METHODOLOGY

The current thesis aimed to address several theoretical and methodological objectives related to rumination. We conducted several studies in order to answer some particular questions.

The general goal of the thesis was the bidirectional investigation between rumination and automatic cognitive processes in distress. In order to achieve this goal we run four studies which focused on the relations between rumination and various cognitive factors.

The first goal of the thesis was to analyze the relations between rumination and core EFs. According to several theoretical accounts (i.e., Joormann, 2010; Whitmer & Gotlib, 2013) deficits in updating working memory capacity, inhibition, and shifting (for a review about core EFs, see: Miyake et al., 2000) are supposed to be responsible for ruminative disposition. However, until now the exact nature of this relationship is unclear. In the first study, a comprehensive literature review of the associations between rumination and core EFs: working memory, shifting and inhibition is proposed (Study 1).

The second objective of the thesis was to extend research on cognitive biases (i.e., attention and interpretation bias) and rumination starting from several recent theories that propose a relation between them (e.g., Mor & Daches, 2015; Hirsch & Mathews, 2012; Koster et al., 2011). This link has been approached in very few studies so far (Studies 2, 3, 4).

A third objective of our research was to look at mechanisms through which rumination could influence emotional problems. More specifically we were interested in the mechanisms through which ruminative disposition (trait rumination) could influence anxiety and response to stressors. Thus, in Study 2 we looked at whether the impact of ruminative disposition on state anxiety before an exam was mediated by attention bias to threat. In Study 3 we evaluated the influence of attention bias to anxious and sad material on state rumination in an experimental context. Furthermore, in this study we also explored the relation between induced cognitive depletion (assessed both subjectively and physiologically) on state rumination.

Finally, our fourth objective was to assess new training procedures, based cognitive bias modification, to reduce ruminative thought. We thus examined whether interpretation bias modification training (CBM-I) could reduce state rumination (Study 4).

To summarize, all studies included in the current thesis aim to clarify our current understanding of rumination, focusing on cognitive factors involved in this process. Study 1 looks at the magnitude of the associations between rumination and executive functions. Studies 2-4 focus specifically on cognitive biases, with Studies 2 and 3 analyzing the link between attention biases and rumination, and Study 4 testing a cognitive bias modification procedure to

reduce state rumination. All studies have important theoretical and practical implications. The structure of studies included in the thesis is presented in Figure 1.

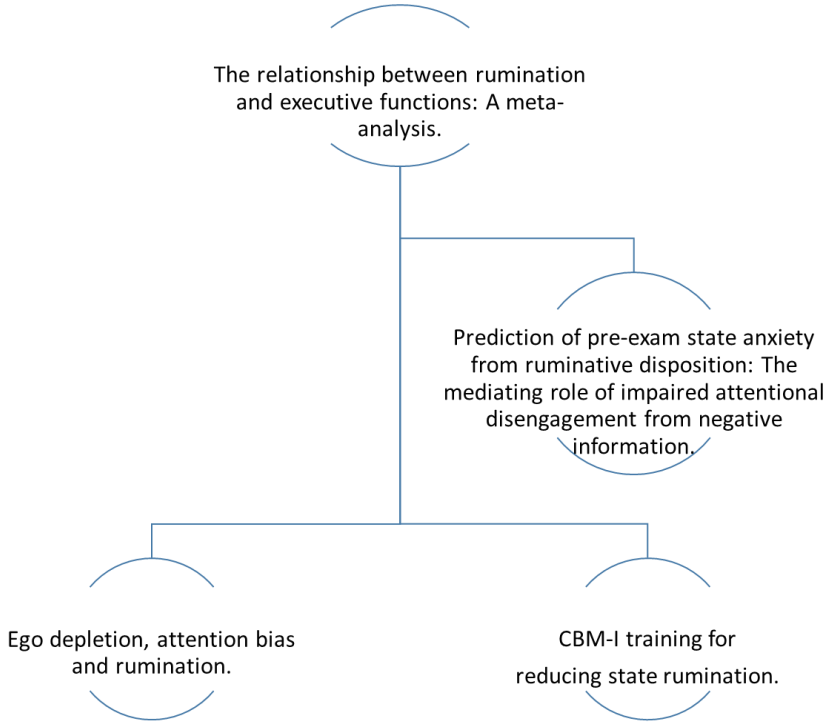

Figure 1. Structure of studies included in thesis

CHAPTER III. ORIGINAL RESEARCH

3.1. Study 1. The relationship between rumination and executive functions: A meta-analysis[1]

Introduction

Rumination refers to a repetitive cognitive process that involves thoughts about symptoms and the implications of these symptoms (Nolen-Hoeksema, 1991). Recent conceptualizations of rumination (Treynor, Gonzalez, and Nolen-Hoeksema, 2003) have identified two factors, "reflection" and "brooding", as rumination subtypes. Reflection refers to *"purposeful turning inward to engage in cognitive problem solving to alleviate one's depressive symptoms",* whereas brooding involves *"a passive comparison of one's current situation with some unachieved standard"* (Treynor et al., 2003, p. 256).

[1] This study is under review at Journal of Psychological Research: Vălenaș, S., & Szentagotai-Tătar, A., (2017). The relationship between rumination and executive functions: A meta-analysis.

Numerous studies highlight the negative effects of rumination in terms of negative emotions, but also underline its negative cognitive outcomes. For instance, rumination prolongs negative mood (Nolen-Hoeksema & Morrow, 1993), enhances negatively biased memories and negative future thinking (e.g. Kuehner, Huffziger, & Liebsch, 2009; Morrow & Nolen-Hoeksema, 1990; Papageorgiou & Wells, 2004; Watkins & Teasdale, 2004). In dysphoric people, rumination impairs executive functioning and autobiographical memory (Watkins & Teasdale, 2001) and reduces problem solving capacity (Ward, Lyubomirsky, Sousa, & Nolen-Hoeksema, 2003). Moreover, rumination is seen as a risk factor for psychopathology, especially for depression, being related to the frequency of depressive episodes, relapse frequency and poor recovery (Nolan et al., 1998). Rumination is considered a transdiagnostic process leading to a number of other psychological problems including anxiety disorders, substance abuse, and bulimic behavior (e.g., Nolen-Hoeksema, Stice, Wade, & Bohon, 2007; Valenas & Szentagotai-Tatar, 2014).

Recent research shows that cognitive processes might be responsible for persistent negative cognition and affect (Joormann, Yoon, & Zetsche, 2007). Although, it has been proved that psychopathology (e.g. depression) is associated with cognitive deficits (Hertel & Rude, 1991), mechanisms underlying this relationship are unclear. Recent models propose that attention bias may be a potential mechanism involved in habitual rumination (for a review see: Koster et al., 2011). In addition, promising results show that addressing executive functions may impact on negative affect and psychopathology (for a review see: Mor & Daches, 2015).

However, even though research on rumination and executive functions (EFs) does exist, results on their association have been mixed. Some studies argue that rumination is related to cognitive impairments and depleted executive resources (Davis & Nolen-Hoeksema, 2000; Joormann, 2010; Koster et al., 2011); others have found no significant relationship between rumination and EFs (Joormann, 2006; Whitmer & Banich, 2007a). Given the growing interest in this topic and the ambiguities regarding the rumination-EFs relationship, we conducted an overview of the literature on this topic using meta-analytical methods.

Executive functions

The concept of executive functions (EFs) refers to independent but related cognitive processes, with both unique and shared individual differences, genetic influences, and neural substrates (Miyake & Friedman, 2012). EFs include various key components such as anticipation and attentional deployment, impulse control and self-regulation, initiation of activity, working memory, mental flexibility and use of feedback, planning ability and organization, and selection of efficient problem-solving strategies (e.g., Anderson, 2008; Jurado & Rosselli, 2007). However, there are three core executive functions, which were first conceptualized by Miyake and colleagues (2000). They proposed a model of EFs which includes three fundamental components of EFs: a) updating of information; b) inhibition of attention and prepotent responses and c) attentional switching (Miyake et al., 2000; Miyake & Friedman, 2012).

According to Miyake et al., (2000) updating refers to constant monitoring and rapid addition/deletion of working memory contents. The generic term of working memory will be used in this article for this component. Working memory functions include mental relatedness, and integration or recombination of information when necessary, playing a crucial role for more complex EFs such as planning or concept formation (Karbach & Unger, 2014).

The concept of inhibition has been inconsistently defined across studies. Miyake and colleagues (2000) defined inhibition as overriding prepotent response tendencies and suppressing attention to irrelevant stimuli as well as unwanted thoughts and emotions; others have defined it as a mental process that overrides, dampens, or deactivates other mental processes or behaviors (e.g., MacLeod, 2007). Cognitive inhibition is used in situations that

require concentration on a specific stimulus while ignoring interference from irrelevant stimuli, multitasking, or in situations which involve the control of automatic or impulsive response tendencies and unwanted emotions (Karbach & Unger, 2014).

The mental ability to shift back and forth between multiple tasks, operations and mental sets is referred to as set shifting (e.g., Miyake et al., 2000; Monsell, 2003)). Shifting is also referred to as attentional switching, task switching or cognitive flexibility (e.g., Miyake et al., 2000; Monsell, 2003). Because there are multiple terms with the same meaning, we use the broad term of shifting in the current study. Shifting ability supports divergent and creative thinking, changing perspectives and developing new ideas (Karbach & Unger, 2014).

The model proposed by Miyake et al. (2000) provides useful support for investigating EFs in relation to cognitive deficits and biases. The present meta-analysis works with the distinction proposed by Miyake (2000) given that the three functions are (1) relatively well - circumscribed and can be clearly defined, (2) well-studied and (3) involved in other complex executive tasks (i.e. planning, reasoning) (Miyake, 2000). Moreover, these EFs are most often studied in relation to rumination.

Rumination – EFs relationship

Several theoretical accounts have attempted to offer explanations for the relationship between EFs deficits and rumination (i.e., Joormann, 2010; Koster, et al., 2011; Whitmer & Gotlib, 2013).

Joormann (2010) proposed that deficits in inhibiting negative material are related to increased risk for depression, and this leads people to ruminate about negative content. She suggested that dysphoric people are more inclined to keeping negative information and material in their working memory, which leads to rumination. Also, deficits in cognitive inhibition may interfere with adaptive emotion regulation strategies and the recall of mood-incongruent material, predisposing to negative mood.

Koster and colleagues (2011) suggested that impaired attentional disengagement from negative information can lead to prolonged processing of self-referent material. They argued that people who experience rumination are characterized difficulties in exercising attentional control in response to negative thoughts. In this context, attentional control is considered the ability to attend to task relevant information and to inhibit distraction by task-irrelevant information (Koster et al., 2011).

Whitmer & Gotlib (2013) hypothesized that negative mood is responsible for ruminative thinking by narrowing the scope of attention and limiting available thoughts, percepts or actions that will be activated in the working memory or available for selection in long term memory. They propose that attentional scope mediates the relation between mood and rumination. Moreover, Whitmer & Gotlib (2013) suggest that differences in attentional scope may account for trait rumination, and that people characterized by a narrow attentional scope tend to engage in rumination as a response to negative mood.

However, although rumination may be explained by EFs deficits, the exact nature of this relationship remains unclear. Though it seems that rumination is related to problems in updating working memory content, a causal relation between the two has been difficult to prove. For example, in a modified Sternberg task, depressive participants with high rumination scores showed difficulties in removing task-irrelevant negative material from their working memory (Joormann & Gotlib, 2008). To examine the causal relation between rumination and working memory, Wanmaker and colleagues., (2015) assessed if working memory training improved working memory capacity and reduced rumination, depression and anxiety. Results revealed no positive effect of training, neither on working memory capacity nor on rumination, depression or anxiety. Following a working memory training, Onraedt and Koster (2014) found no difference in working memory performance for emotional material.

Regarding the rumination-inhibition relationship, data are relatively mixed. For example, results of one study indicated that inducing rumination influenced cognitive inhibitory capacity in a random generation task (Watkins & Brown, 2002), while another study showed that negative information was difficult to inhibit in depressive ruminators (Joormann, 2006). Philippot and Brutoux (2008) have shown that rumination leads to impaired inhibition in the Stroop task. However other studies found no relation between rumination and inhibition (Goeleven, De Raedt, Baert, & Koster, 2006).

Compared to inhibition and working memory, shifting has been less investigated in relation to rumination. Research findings show that ruminators are characterized by a higher number of perseverative errors on the Wisconsin Card Sorting Task (WCST) compared to controls, suggesting a general set-shifting impairment (Davis & Nolen-Hoeksema, 2000). Some studies reported that high ruminators showed impaired set shifting compared to low ruminators in both emotional and non-emotional tasks (De Lissnyder et al., 2010). Additionally, Owens and Derakshan (2013) found that high ruminators made more switching errors. In contrast, two studies reported that switching impairments were not associated with rumination in an antisaccade task (De Lissnyder, Derakshan, De Raedt, & Koster, 2011; Whitmer & Banich, 2007).

Current study

Despite the increased interest in the EFs-rumination relationship, an analysis of the literature reveals numerous inconsistencies. For example, it is not yet clear if: (a) an actual association between EFs and rumination exists and how strong this association is; (b) training cognitive functions is effective in reducing rumination; (c) stimulus valence (i.e., positive, negative) impacts rumination. We believe meta-analytical methods could provide a clearer image on the EFs-rumination relation, and could provide answers to current ambiguities in the literature.

This approach has both theoretical and practical implications. From a theoretical point of view, the study will shed light on the strength of the rumination-EFs relation that has been proposed by several theoretical accounts, and will identify the EFs more strongly related to rumination. From a practical perspective, our results can inform future psychological interventions on the EFs that should be targeted primarily to reduce rumination or emotional problems associated with rumination (e.g., depressive symptoms).

Method

We searched and selected all possibly relevant articles that reported data on the relation between rumination and executive function in various forms (e.g., correlations, mean differences between groups etc.). The search strategy, inclusion and exclusion criteria, the coding scheme and procedure, and statistical methods used to analyze the data are detailed below.

Literature Search

To maximize exhaustiveness, several complementary approaches were used to search for relevant articles. First, a systematic literature search was done in PsycInfo, PubMed, Scopus and Web of Science to identify empirical articles, published until the end of February 2016 in peer reviewed journals. Combinations of the following search terms were entered: (“ruminat” OR “rumination” AND "executive function" OR “EF” OR “inhibition” OR “working memory" OR “WM” OR "attention control" OR "cognitive flexibility" OR “shift” OR "attentional shift" OR "prefrontal area" OR “neuropsychology”). The search yielded 1123 papers, which were subsequently checked for relevance based on the inclusion and exclusion criteria (see below).

As a second search strategy, reference lists of articles that addressed the topic of the meta-analysis and of all papers included in the meta-analysis that resulted from the two other search strategies were reviewed to check for additional relevant papers that were possibly missed in the previous steps.

Selected studies

All 1123 papers resulting from database search were evaluated on the inclusion and exclusion criteria presented below. The selection of articles followed a stepwise process. An initial broad selection was performed, excluding articles that did not meet selection criteria based on the title and/or abstract. A final 65 papers were selected for inclusion in the meta-analysis. The distribution of selected articles across the years showed that the first study (that met our criteria) was published in 2000, after which interest in this topic grew. One rater assessed the relevance of papers based on the inclusion and exclusion criteria.

Inclusion and Exclusion Criteria

Only studies meeting the following criteria were included in the analysis. First, articles were included if they reported empirical data involving a measure of rumination (trait, brooding*, reflection* or induced) and a measure of executive functioning (Shifting, Inhibition and Working Memory). Second, to be more comprehensive, we included studies that focused on (1) shifting (used here as an umbrella term for processes described such as "cognitive flexibility", "attentional shifting/switching", "mental flexibility/set shifting", "cognitive shifting"), (2) inhibition (described as "cognitive inhibition" or "inhibitory control of attention") and (3) working memory (described as "holding information in mind and manipulating it") .We excluded studies that defined EFs differently than they were defined by Miyake. Therefore, we excluded studies that operationalized executive functions as "divided attention", "executive control", "selective attention" or "sustained attention". Studies that conceptualized executive function as "attentional bias", "cognitive function", "behavioral inhibition" or "autobiographical memory" were not included either.

Third, executive functions were manipulated by training in several studies; if the manipulation was not effective, only pre-intervention data were included. In the case of multiple ways of data reporting, correlation coefficients were preferred. Forth, if multiple measures were reported in a study, only baseline data were included. Finally, only studies that were published or communicated in English were included. Sixty four articles satisfied the inclusion criteria

Total rumination score was preferred to subscale scores; however, if a total rumination score was not reported, subscale scores (e.g., brooding, reflection, distraction) were included.

Procedure

For every study included in the meta-analysis we recorded the following variables: (1) study identification (i.e., author, publication year, study design); (2) type of executive function (i.e., working memory, shifting, inhibition, other); (3) rumination measure; (4) executive function measure (e.g., accuracy, cost scores, reaction time, total score, errors); (5) sample type (i.e., clinical, subclinical/analogue, unselected); (6) recruitment type (i.e., volunteers, students, patients); (7) sample size; (8) mean age of participants; and (9) percentage of females.

Moderators

There are some potential moderators of the relationship between executive functions and rumination, as identified through literature search and suggestions from previous studies (Nolen-Hoeksema et al., 2008). After potential studies were analyzed, we decided to take into account the following moderators:

(1) **Sample type:** clinical – diagnosed by clinical interview; analogue – selected based on high scores on a scale; healthy or unselected population

(2) **Recruitment type:** community volunteers, university students, patient samples
(3) **Rumination measure:** CRSQ, RRS–22, RRS–26, RDQ, RSQ, RSS, Padua, experimentally induced
(4) **Executive function measure:** accuracy, cost scores, reaction time, total score, errors
(5) **Mean age of participants**
(6) **Sample size**
(7) **Total percentage of female participants in the sample**
(8) **Design:** correlational, experimental
(9) **Emotional valence of stimuli used in the executive function measure:** emotional, non-emotional

For data analysis, we chose *r* coefficient to calculate the effect size (Borenstein, Hedges, Higgins, & Rothstein, 2009). According to Cohen's (1988) classification of effect sizes, r is considered a small effect if smaller or equal than 0.3, a medium effect if between 0.3 and 0.5, and a large effect if 0.5 or higher.

All the analysis in the present study were run using Comprehensive MetaAnalysis, Version 2.2.046 (Borenstein et al., 2005).

Results

Executive Functions – Rumination Relation; Overall Effect

We performed separate analyses for executive functions taken overall, and for working memory, inhibition and shifting. Similarly, we performed moderation analysis in order to find significant moderators of the executive functions – rumination relationship.

The overall effect size of the executive functions (working memory, inhibition, and shifting) – rumination relation, was calculated from 64 articles, including 70 studies and 4916 participants. Results based on a random effect model showed no relationship between executive functions and rumination, r = 0.09, 95% confidence interval (CI) 0.04, 0.15, Z = 3.42, p = 0.001. There was evidence of a moderate level of heterogeneity, as shown by the following indicators, $Q(70) = 289.806$, $p < .001$, I^2=75.846. We analyzed whether one of the potential moderator variables could explain the heterogeneity in the overall effect. No significant moderators of the executive functions-rumination relationship on the overall outcome were found.

Working Memory – Rumination relation

The effect size of the rumination – working memory relation was calculated from 28 studies including 2915 participants. The results showed no relationship between working memory and rumination, r = 0.06, 95% confidence interval (CI) -0.01, 0.14, Z = 1.54, p = 0.12. There was evidence of a moderate level of heterogeneity, as shown by the following indicators, $Q(32) = 132.47$, $p < .001$, I^2 = 75.84. We looked at whether one of the potential moderator variables could explain the heterogeneity of the overall effects. We found no significant moderators of the working memory-rumination relationship.

The Shifting – Rumination relation

The effect size of the shifting – rumination relation was calculated from 24 studies including 2979 participants. Results showed a small significant relation between shifting and rumination, r = 0.17, 95% confidence interval (CI) 0.08, 0.25,Z = 3.95, p = 0.001. Additionally, fail-safe *n* analysis indicated that 381 studies with null-results would be needed in order for the combined 2-tailed *p*-value to exceed 0.050. There was evidence of a moderate level of heterogeneity, as shown by the following indicators, $Q(23) = 110.69$, $p < .001$, I^2 = 79.22. We analyzed whether one of the potential moderator variables could explain the heterogeneity of the data, but we found no significant moderator.

Inhibition – Rumination relation

The effect size of the inhibition – rumination relation was calculated from 30 studies including 2018 participants. Results showed a small significant effect of the relation between shifting and rumination, $r = 0.11$, 95% confidence interval (CI) 0.02, 0.12, $Z = 2.38$, $p < 0.001$. Additionally, fail-safe *n* analysis indicated that 115 studies with null-results would be needed in order for the combined 2-tailed *p*-value to exceed 0.050. There was evidence of a moderate level of heterogeneity, as shown by the following indicators, $Q(28) = 108.51$, $p < .001$, $I^2 = 74.19$. We analyzed whether one of the potential moderator variables could explain the heterogeneity of the data. Moderation analysis confirmed that sample type $Q(2) = 8.507$, $p = .014$, and sample size $Q_m = 4.08$, $p = 0.04$, significantly influenced effect size.

Discussion

The present meta-analysis examined the relation between rumination and EFs: working memory, inhibition and shifting. We performed a quantitative review of 70 studies and examined potential moderators that could explain the heterogeneity of the data.

Main findings

The nature of the association between rumination and executive functions deficits still raises many controversies (Wagner, Alloy, & Abramson, 2015). The primary aim of the current study was to provide a clear measure of the strength of the rumination-EFs relationship. First, our results show that there is no significant relationship between rumination and EFs overall ($r = .09$).

Second, the current results point to different effect sizes of the associations between rumination and the three executive functions analyzed. Although theoretical models propose a relation between rumination and working memory, our results do not confirm this link ($r = .06$). This result is supported by previous experimental research that did not find a relation between these constructs (e.g., Onraedt & Koster, 2014; Wanmaker et al., 2015). That is, working memory training does not seem to impact rumination (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Onraedt & Koster, 2014), nor does it lead to persistent or generalized effects (Melby-Lervåg & Hulme, 2013; Shipstead, Redick, & Engle, 2012; Wanmaker et al., 2015). The lack of relationship could also be explained by methodological issues, such as inadequate controls or measures (Shipstead et al., 2012).

A small and significant association was found between rumination and inhibition ($r = .11$). This finding supports the hypothesis that ruminators may have difficulties in disengaging from unreachable goals or in controlling negative thoughts due to cognitive inhibition deficits (e.g., Joormann, 2010; Martin & Tesser, 1996). However, we need to approach the results cautiously considering the magnitude of the effect size. These results are in line with some previous ones showing that rumination and inhibition are related. For example, in a cross-sectional study conducted on an adult sample, Whitmer and Banich (2007) found that rumination was negatively associated with inhibition. Moreover, the association was present for both subtypes of rumination: brooding and reflection.

The absence of clinically-significant executive dysfunctions and the non-clinical nature of most samples may be a possible explanation for the small effect size of the rumination-inhibition relation (see Aker, Harmer, & Landrø, 2014; Goeleven et al., 2006). In addition, finding a positive relation in smaller samples may be the effect of the heterogeneity of the samples included in studies, many covariates being unbalanced and possibly leading to power issue. These positive results need to be taken with caution. For instance, the rumination-inhibition relation was significant in both subclinical/analogue and in mixed samples, but this may be due to the limited number of studies and the reduced diversity among studies.

Moreover, the small EFs-rumination relationship may also be explained by the complexity of cognitive inhibition, as inhibition of external distracters, of internal distracters, and of prepotent responses are partially separable components (Aker et al., 2014; Friedman & Miyake, 2004). Therefore it is supposed that different aspects of inhibition can differently influence the rumination outputs, the EFs – rumination relationship depending on the inhibition task used (Aker et al., 2014).

Finally, there was a small and significant effect size of the rumination-shifting relation (r = .17). From a theoretical perspective, it has been suggested that (negative) repetitive thoughts experienced by (trait) ruminators may be a manifestation of mental inflexibility (e.g. Davis & Nolen-Hoeksema, 2000). Mental inflexibility is considered a core feature of ruminators, due to low shifting ability from negative to positive thoughts or goals (Altamirano, Miyake, & Whitmer, 2010). However, results have been inconsistent regarding this relationship, which is still under debate. Previous research has suggested that rumination requires a response to a negative mood, and is usually seen a process of trying to resolve problems (e.g. Papageorgiou & Wells, 2003). Although, studies show that rumination can appear in non-clinical samples (e.g., Moulds, Kandris, Starr, & Wong, 2007), our hypothesis is that those with psychopathology have numerous deficits in shifting abilities and are more willing to remain focused on their problem, ruminating on it. Therefore, we think a higher effect size of rumination-shifting relation would be better expressed in clinical samples.

As our findings showed significant heterogeneity of the investigated outcomes, we performed moderation analyses. The only significant moderators were found in the rumination – inhibition relationship. We found that sample type (i.e., clinical – diagnosed by interview; analogue – high score on a scale; unselected) was a moderator of the association between rumination and inhibition. The rumination – inhibition relation was significant in samples which were selected based on high scores on scales or which were unselected for any category. We run 2x2x2 comparisons between moderator modalities (clinical, analogue, unselected) in order to find the differences between significant moderators. Results showed that there were no differences between analogue and unselected samples in moderating the association between rumination and inhibition (see Table 4). The other significant moderator was sample size, with a higher effect size of the rumination-inhibition association found in smaller samples.

Limitations

In line with the limitations of the studies included, the results of the present meta-analysis need to be interpreted in the light of several limitations. The *first* limitation is represented by the heterogeneity of the data. Studies included showed substantial heterogeneity and small confidence intervals for I^2 for all outcomes. The variation of the data could not be explained by the moderators we considered in the analyses. Therefore, future studies should focus on additional moderators that could impact the rumination-EFs relation. *Second*, another important limitation is related to the EFs measures. Statistical power of EFs measures could be a problem, and it might have prevented the finding of significant associations due to the substantial variability and inconsistencies in measurement. *Third*, the heterogeneity of definitions and conceptualizations of terms used for EFs was another limitation, as it was very difficult to connect a concept to a specific EF. For instance, we found multiple and different definitions for the same concept (see cognitive inhibition, e.g., Joormann, 2010; Whitmer & Gotlib, 2013); different terms for the same concept (see shifting e.g., Karbach & Unger, 2014); or different conceptualizations of the same concept (see cognitive control, e.g., Joormann, 2010; Mor & Daches, 2015). *Fourth*, we only found 4 studies that examined the EFs-rumination relation while manipulating rumination. Furthermore, only 4 studies manipulated EFs in order to reduce rumination, which are insufficient for testing moderation. Probably, a

greater number of studies using these methods would better highlight the EFs – rumination relationship.

To summarize, the present meta-analysis aimed: (1) to provide an estimate of the overall and specific effect sizes of the relationship between rumination and executive functions (EFs): working memory, shifting and inhibition; and (2) to test possible moderators of these associations. The overall effect size revealed no relationship between rumination and EFs. Also, there was no relationship between rumination and working memory. However, a small effect sizes was found for the association between rumination and shifting and between rumination and inhibition. The only significant moderators were sample type and sample type, which moderated the rumination-inhibition relation.

Future directions and clinical implications

Future investigations are still needed to explore and clarify the EFs-rumination relation. Longitudinal studies would be very important in examining this link, as they could highlight how changes in EFs prospectively predict changes in the development of trait rumination or psychopathology (e.g. depression). On the other hand, future studies should also employ the rumination-induction paradigm more frequently, in order to examine the impact on EFs (Wagner et al., 2015). Only a small number of studies have investigated the relation between rumination and EFs in clinically depressed samples, and they did not look at this association in the context of other disorders (e.g., anxiety). For example, recent studies have shown that both rumination and EFs are related to anxiety disorders (e.g. Brozovich & Heimberg, 2008; Cristea, Matu, Szentagotai Tatar, & David, 2013; C. MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Valenas & Szentagotai, 2014).

Regarding EFs, future studies should seek to improve their assessment. The reliance on self-reports to assess EFs (e.g., the Behavior Rating of Executive Function; BRIEF; Rabin et al., 2006) may be a limitation due to the fact that people may not have insights regarding cognitive impairments or distortions. Second, a frequent limitation is related to the reliability and validity of tasks employed to assess EFs impairments in relation to emotional and non-emotional material (see De Lissnyder et al., 2010). This improvement of measures would be necessary to control for the influence of emotional information on EFs or rumination tasks.

From a clinical perspective, a better understanding of the relation between EFs, rumination, and pathology could have important implications, informing future treatment programs. Considering that traditional Cognitive Behaviour Therapy (CBT) focuses on information transmission in order to facilitate the processing of new information and to restore cognitive control (Baert, Koster, & De Raedt, 2011), the development of novel treatment techniques that address decreased cognitive control could be useful in remediating information processing biases, and thus in treating psychopathology (i.e., anxiety or depression).

3.2. Study 2. Prediction of pre-exam state anxiety from ruminative disposition: The mediating role of impaired attentional disengagement from negative information[2]

Introduction

Cognitive theories emphasize the importance of cognitive vulnerabilities in psychological distress (Beck, Rush, Shaw, & Emery, 1979). In recent years, significant attention has been devoted to understanding the independent and combined contributions of various cognitive vulnerability factors to emotional distress, and the relationships among these vulnerability factors (Epkins, Gardner, & Scanlon, 2013; Fergus & Wu, 2011; Mathews & MacLeod, 2005; Reardon & Williams, 2007). The current study focused on examining the impact of two such factors, ruminative disposition and attentional bias to negative information, on levels of state anxiety experienced by students prior to a mid-term exam.

Ruminative disposition concerns the habitual tendency to engage in repetitive thinking about one's negative feelings and problems, and their possible causes and consequences (Nolen-Hoeksema, 1991; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). This type of repetitive thinking impairs emotion regulation, prolonging and exacerbating distress (Lyubomirsky & Nolen-Hoeksema, 1993, 1995; Nolen-Hoeksema et al., 2008). Although ruminative disposition has been studied most extensively in relation to depression, it also appears to be a risk factor for anxiety, as shown by both cross-sectional and longitudinal evidence (Alloy et al., 2012; Harrington & Blankenship, 2002; Michl, McLaughlin, Shepherd, & Nolen-Hoeksema, 2013; Nolen-Hoeksema et al., 2008). Several studies have linked elevated ruminative disposition to increased anxiety symptoms in students (Aldao & Nolen-Hoeksema, 2010; Calmes & Roberts, 2007; Segerstrom, Tsao, Alden, & Craske, 2000). Young and Dietrich (2015) have recently reported that ruminative disposition is a significant predictor of anxiety symptoms in adolescents over a period of six months, and it has been suggested that individual differences in ruminative disposition may be implicated in the relation between stressful life events and anxiety symptoms (Hankin, 2009; Michl et al., 2013). Rumination related to social evaluation has been associated with increased state anxiety in individuals with heightened vulnerability to social anxiety, suggesting that a heightened tendency to engage in rumination may contribute to state anxiety elevation in contexts of particular personal relevance (McEvoy & Kingsep, 2006).

Given the maladaptive emotional consequences and clinical significance of habitual rumination, investigators have sought to illuminate the cognitive mechanisms that underpin this disposition (Beckwe, Deroost, Koster, De Lissnyder, & De Raedt, 2014). Several theoretical accounts have emphasized the potential importance of attentional processes in rumination (for reviews see: Koster et al., 2011; Whitmer & Gotlib, 2013), and it has been hypothesized that attentional bias to negative information may be involved in ruminative thinking. Koster and

[2] This study has been published: Vălenaş, S. P., Szentágotai-Tătar, A., Grafton, B., Notebaert, L., Miu, A. C., & MacLeod, C. (2017). Prediction of pre-exam state anxiety from ruminative disposition: The mediating role of impaired attentional disengagement from negative information. Behaviour Research and Therapy, 91, 102-110. Doi: https://doi.org/10.1016/j.brat.2017.01.014.

colleagues have argued that heightened ruminative disposition may be specifically associated with difficulty disengaging attention from negative information (Koster et al., 2011).

Using the conventional attentional probe task (MacLeod, Mathews, & Tata, 1986), two studies have confirmed a relation between trait rumination and attentional bias to negative information in depressed patients (Donaldson, Lam, & Mathews, 2007; Joormann, Dkane, & Gotlib, 2006). However, as has been noted elsewhere, this attentional assessment approach does not permit clear differentiation between biased attentional engagement with negative information, and biased attentional disengagement from negative information (Grafton & MacLeod, 2013). Therefore, in a more recent study, Grafton, Southworth, Watkins, and MacLeod (2016) employed an amended attentional assessment procedure designed to dissociate these two facets of attentional bias to negative information. In this version of the attentional probe task, differentially valenced information appears either distally from participants' initial attentional focus, in order to reveal individual differences in the degree to which negative information selectively captures attention (attentional engagement bias), or it appears proximal to participants' initial attentional focus, in order to reveal the degree to which negative information selectively holds attention (attentional disengagement bias). Grafton et al.'s findings supported Koster et al.'s hypothesis that elevated ruminative disposition is associated with impaired attentional disengagement from negative information, rather than facilitated attentional engagement with negative information (Grafton et al., 2016).

It is well established that attentional bias to negative information can serve to increase the intensity of state anxiety responses to stressors (c.f. MacLeod & Mathews, 2012). When taken together with the evidence that heightened ruminative disposition is associated both with increased state anxiety symptoms, and impaired attentional disengagement from negative information, this invites the hypothesis that the impact of ruminative disposition on state anxiety responses to stressors may be mediated by the attentional disengagement bias that characterizes this disposition. The present study was designed to empirically evaluate this hypothesis, by first assessing ruminative disposition in a student sample, and then examining both the state anxiety experienced by these students, and their patterns of attentional bias to exam-relevant negative information, immediately prior to an important mid-term exam.

We anticipated that the initial measure of ruminative disposition would predict pre-exam state anxiety, and would do so independently of trait anxiety, and independently of the more adaptive form of self-attentive thinking known as reflection (Trapnell & Campbell, 1999). We also anticipated that elevated ruminative disposition would be associated with impaired attentional disengagement from exam-relevant negative information, but not enhanced attentional engagement with such information, prior to exam. Additionally, we anticipated that this attentional bias would predict levels of pre-exam state anxiety. Assuming confirmation of these expected effects, it was our intention to directly test, using mediation analysis, the hypothesis that the impact of ruminative disposition on state anxiety experienced during the pre-exam period would be mediated by rumination-linked impairment in attentional disengagement from exam-relevant negative information.

Method

Participants

Participants were 134 (111 women) first-year psychology students (age M = 20.4, SD = 3.87 years) from Babeș-Bolyai University, Cluj-Napoca. The results of two participants were excluded from analysis as they failed to comply with instructions regarding the attentional-probe

task (i.e., they completed the task a day before the exam instead of on the day of the exam).Written consent was obtained from all participants prior to the study and they received course credit for taking part in the experiment. The study was approved by the Ethics Committee of Babeș-Bolyai University.

Self-report Measures

State Trait Anxiety Inventory (STAI, Spielberger, Gorsuch, & Lushene, 1970)**,** *Rumination/Reflection Questionnaire (*RRQ, Trapnell & Campbell, 1999) and *Ruminative Response Scale* (RRS, Nolen-Hoeksema & Morrow, 1991) were used. All scales showed good psychometric properties.

Attentional probe task

Attentional biases to threat were assessed using the attentional probe task employed by Grafton, Watkins, and MacLeod (2012) and Grafton et al. (2016) to differentiate selective attentional engagement with, and disengagement from, negative information. The stimuli employed in the present study comprised 48 negative words (i.e., exam-relevant) and 48 neutral words, each paired with a length-matched non-word. An independent sample of students (N = 23) rated the words for emotional arousal, negative emotional valence and relevance for test anxiety, using 5-point Likert scales (1, not at all; 5, very much). These ratings confirmed that relative to the neutral words, the negative words were characterized by significantly higher levels of emotional arousal ($t[22] = 13.81$, $p < 0.001$, Cohen's $d = 3.5$), negative emotional valence ($t[22] = 16.52$, $p < 0.001$, Cohen's $d = 4.18$), and relevance for test anxiety ($t[22] = 15.95$, $p < 0.001$, Cohen's $d = 3.86$).

In this attentional assessment task, participants' attention is initially anchored in either an upper or lower screen location, where they must first apprehend the orientation of a briefly exposed anchor probe. Next, a pair of letter strings is presented, comprising one word and one non-word. Finally a target probe is presented in the location where one of these two letter strings was shown, and the participant is required to determine whether its orientation matches that of the anchor probe. Of critical importance, the locus in which the word member of the letter string pair is presented is systematically manipulated. Specifically, on some trials, the word is displayed in the locus distal to the initial attentional focus of the participant (i.e. attentional engagement bias assessment trials), and on other trials it is displayed in the locus of the participant's initial attentional focus (i.e. attentional disengagement bias assessment trials). The degree to which speeded responding to target probes in the locus of the words compared to non-words is greater when these words are negative, as opposed to neutral, in emotional tone, provides an index of heightened attentional bias to negative information. The tendency for attention to be selectively drawn to distal negative information (i.e., attentional engagement bias) is revealed by this measure of heightened attention to negative words, when the words were presented distally from initial attentional focus. The tendency for attention to remain more firmly held by proximal negative information (i.e. attentional disengagement bias) is revealed by this measure of heightened attention to negative words when these words were presented in the locus of initial attentional focus.

As shown in Fig. 1, each trial started with the presentation (1000 ms) of two rows of asterisks, separated by 3 cm, with a row of arrows between them. The arrows pointed toward the upper or lower row of asterisks, with equal frequency. Participants were instructed to direct initial attention to the screen region indicated by the arrows. Immediately following the disappearance of the asterisks, an anchor probe was displayed (150 ms) in this attended region of the screen. The anchor probe was a small (5 mm) grey line, sloping upwards 45 degrees, to the left or to the right,

with equal frequency. A letter string pair including a word and a non-word was then presented (500 ms), with one string appearing in each of the regions previously occupied by an asterisk string. On half the trials, the word member of the pair was presented in locus of initial attention, where the anchor probe has just appeared (attentional disengagement bias assessment trials). On the remaining half of the trials, the word member of the pair was presented in the opposite screen region, distal from the locus of initial attention (attentional engagement bias assessment trials). After the letter string pairs disappeared, a target probe was shown in one of the two screen regions, with equal probability. This target probe was also a 5mm sloping line, and participants were required to quickly indicate whether the slope direction of the target probe matched that of the anchor probe, which was the case on half of the trials. Responses were registered by pressing either the right or left button of the mouse, to respectively indicate that the slopes of the target and anchor probes were or were not the same. After receiving 16 practice trials, participants completed 384 assessment trials, across which the 96 stimulus words and their length matched non-words were each shown four times, once in each of the unique conditions resulting from the nested combination of the two factors: attentional disengagement assessment trial vs. attentional engagement assessment trial, and target probe in locus of word vs target probes in locus of non-word stimulus pair member.

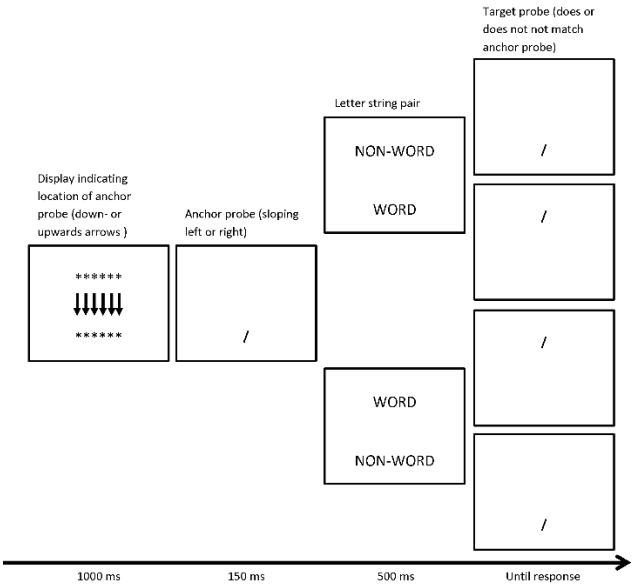

Figure 1. Attentional probe task

Attentional bias to negative words was indexed by the degree to which speeding of responses latencies to target probes in the loci of words, relative to target probes in the locus of non-words, was disproportionately greater when these words were negative rather than neutral in emotional tone. As previously described by Grafton et al. (2012, 2016) this task allows for the computation of attentional bias to negative words separately on attentional disengagement bias assessment trials, and on attentional engagement bias assessment trials, to respectively index selective attentional disengagement from and selective attentional engagement with negative information. The resulting disengagement bias index score indicates the degree to which attention was selectively held by the emotionally negative information compared to the neutral information. The engagement bias index score indicates the degree to which attention was selectively drawn to the emotional negative information compared to the neutral information.

Procedure

Participants filled in the RRS and STAI-T two weeks before the exam. The day before the exam, they received an e-mail containing detailed instructions on installing and running the attentional bias assessment task on their computer. On the morning of the exam (scheduled at 11 a.m.), participants filled in the STAI-S scale and completed the attentional bias assessment task. Participants were instructed to fill in the scale and complete the attentional task at least one hour after waking up. The time between attentional assessment and exam varied (M = 151.32, SD = 46.49 minutes), but was not significantly correlated with state anxiety or attentional biases (all *p*s> 0.444), and so this variable was excluded from analysis. Instructions for the attentional task emphasized the need for accuracy, but stressed that the response should be made as quickly as possible without compromising accuracy. After the exam, participants were debriefed.

Data analysis

Multiple linear regression was used to investigate whether the initial RRQ measure of ruminative disposition predicted variation in state anxiety before exam, whether variation in this disposition was related specifically to biased attentional disengagement from negative information, and whether this attentional bias was related to pre-exam state anxiety.

Prior to computing attentional bias index scores, response latencies from the attentional task were prepared in accordance with the statistical recommendations of Leys, Ley, Klein, Bernard, and Licata (2013), and following the previously validated procedure adopted by Grafton et al. (2012, 2016). Probe discrimination latencies that fell further than 2.5 times from each participant's median latency were eliminated, and median probe discrimination latencies were then calculated for each condition. Attentional biases index scores were then computed using the following formulas:

Disengagement Bias Index Score = (Anchor probes proximal to negative word in letter string pair: RT for target probes distal to negative word - RT for target probes proximal to negative word) - (Anchor probes proximal to neutral word in letter string pair: RT for target probes distal to neutral word - RT for target probes proximal to neutral word);

Engagement Bias Index Score = (Anchor probes distal to negative word in letter string pair: RT for target probes distal to negative word - RT for target probes proximal to negative word) - (Anchor probes distal to neutral word in letter string pair: RT for target probes distal to neutral word - RT for target probes proximal to neutral word).

Multiple regression was used to examine whether RRQ rumination and reflection predicted state anxiety, and attentional disengagement bias and attentional engagement biases; and whether attentional disengagement bias and attentional engagement biases predicted state anxiety. Trait anxiety was included in the first step in all models in order to control for its potential effects. The corrected bootstrapping method, with 1000 iterations (Shrout & Bolger, 2002), was then used to test whether attentional biases to exam-related words were significant mediators in the relation between ruminative disposition and pre-exam state anxiety. The PROCESS macro for SPSS was used to carry out this mediation analysis (Hayes, 2013). Two independent models were tested, with attentional disengagement bias and attentional engagement bias as potential mediators. Indirect effects are significant if the 95% bootstrapping confidence interval (CI) does not include zero. These effects were followed up using trait anxiety as covariate. In this report, the effect size of the indirect effect was indexed by Preacher and Kelley's k^2, based on the ratio of the obtained indirect effect to the maximum possible indirect effect (Preacher & Kelley, 2011). Small, medium and large effect sizes are defined as .01, .09 and .25 (Preacher & Kelley, 2011). All statistical analyses were run in SPSS.

Results

Did ruminative disposition predict pre-exam state anxiety?

We carried out a stepwise regression analysis with pre-exam state anxiety scores as the outcome. STAI-T trait anxiety scores were entered in step 1, and significantly predicted 10.9% of the variance in state anxiety ($p = 0.001$). The two RRQ measures, rumination and reflection, were added in step 2, which significantly improved the model ($p< 0.001$). Reflection scores did not significantly predict independent variance in state anxiety ($p = 0.808$). In contrast, rumination scores significantly predicted a further 13.4% of state anxiety, independently of trait anxiety and reflection. Therefore, as anticipated, the measure of ruminative disposition independently predicted variation in the level of state anxiety experienced during the pre-exam period.

To address this question, we carried out two regression analyses in which RRQ rumination and reflection scores were the predictors, and attentional disengagement bias index score (Model 1) and attentional engagement bias index scores (Model 2) were the outcomes. STAI-T was included in Step 1 of both models.

The model in which attentional disengagement bias index score was the outcome was not significant in Step 1 ($p = 0.692$), when only STAI-T was included as predictor. The model became significant ($p = 0.002$) only after entering RRQ scores as predictors in Step 2, and accounted for 12.4% of the variance in attentional disengagement bias index score. As expected, only RRQ rumination showed an independent association with attentional disengagement bias index scores. Specifically, higher levels of dispositional rumination were associated with greater impairment of attentional disengagement from negative information. No such association was evident between reflection scores and the attentional disengagement bias index scores.

The model in which attentional engagement bias index score was the outcome was significant neither in Step 1 ($p = 0.457$), when STAI-T was entered as predictor, nor Step 2 ($p = 0.145$), after adding RRQ rumination and reflection as predictors.

Therefore, as anticipated, heightened ruminative disposition was characterized by impaired attentional disengagement from, but not by facilitated attentional engagement with, exam-relevant negative information during the pre-exam period.

Did attentional bias predict pre-exam state anxiety?

To determine whether attentional bias to exam-relevant negative information was associated with heightened state anxiety during the pre-exam period, we conducted a regression analysis in which pre-exam state anxiety score was the outcome, and attentional disengagement bias index score and attentional engagement bias index score were the predictors. Again, STAI-T scores were entered in step 1 (once more significantly predicting 10.9% of the variance in state anxiety, $p = 0.001$). Adding the two attentional bias index scores in step 2 significantly improved the model ($p< 0.001$). However, it was the attentional disengagement bias index scores alone that predicted state anxiety ($p< 0.001$), independently accounting for 14.6% of the variance in pre-exam state anxiety levels. In contrast, the attentional engagement bias index scores did not significantly predict state anxiety ($p = 0.874$). Therefore, the level of pre-exam state anxiety was a function of the degree to which participants displayed impaired attentional disengagement from exam-relevant negative information, rather than the degree to which they displayed facilitated attentional engagement with such negative information.

Having verified that heighted ruminative disposition was associated with both elevated state anxiety and impaired attentional disengagement from exam-relevant negative information

during the pre-exam period, and that this attentional disengagement bias predicted variance in pre-exam state anxiety, we proceeded to test our central hypothesis. Specifically, we carried out mediation analysis to determine whether attentional disengagement bias index scores mediated the observed relation between RRQ rumination scores and the STAI-S measure of state anxiety prior to the exam. The bootstrapping CI [0.02, 0.28] did not include zero, which indicates that bias in attentional disengagement from threat did indeed significantly mediate the observed relation between ruminative disposition and pre-exam state anxiety (effect size k2 = 0.07). This indirect effect remained significant when controlling for STAI-T scores, with the bootstrapping CI [0.03, 0.35] continuing to exclude zero.

When these analyses were repeated, using attentional engagement bias index scores rather than attentional disengagement bias index scores as the candidate mediator, as expected, there was no evidence of significant mediation. The bootstrapping CI [-0.04, 0.12] included zero, which indicated that biased attentional engagement with exam-relevant negative information was not a significant mediator in the observed relation between ruminative disposition and pre-exam state anxiety. Controlling for STAI-T scores did not change this result, with the bootstrapping CI [-0.02, 0.17] continuing to include zero.

Therefore, consistent with the hypothesis under test, the association between ruminative disposition and pre-exam state anxiety was mediated specifically by impaired attentional disengagement from exam-relevant negative information.

Discussion

This study examined the relationship between rumination, attentional bias, and pre-exam anxiety, to directly test the hypothesis that the expected association between ruminative disposition and pre-exam state anxiety would be mediated by impaired attentional disengagement from exam-relevant negative information. The results replicate and extend a number of previous findings, and provide the first empirical support for the mediational hypothesis under test.

We found that ruminative disposition predicts state anxiety over and above trait anxiety, and independently of reflection. Prior research, some of it also carried out on student samples, has found that ruminative disposition is related to anxiety symptoms (Aldao & Nolen-Hoeksema, 2010; Calmes & Roberts, 2007; Michl et al., 2013; Segerstrom et al., 2000), and shown that experimentally inducing rumination can increase state anxiety in the laboratory (McLaughlin, Borkovec, & Sibrava, 2007; Wong & Moulds, 2009). However, this is one of the few studies to show that an initial measure of ruminative disposition predicts variability in levels of state anxiety experienced outside the laboratory, when approaching a real-world stressor. This lends weight to the idea that repetitive negative thinking may be intimately involved in increased susceptibility to experience state anxiety (McEvoy & Kingsep, 2006). Elevated ruminative disposition may predispose the individual not only to experience anxiety symptoms (Alloy et al., 2012; Calmes & Roberts, 2007; Michl et al., 2013), but also to display higher levels of state anxiety when approaching stressful situations.

Unlike rumination, there was no indication in the present study that trait reflection was related to pre-exam state anxiety. This reinforces the importance of distinguishing between maladaptive and adaptive forms of self-focused thinking (Joormann et al., 2006; Segerstrom, Stanton, Alden, & Shortridge, 2003; Trapnell & Campbell, 1999). To our knowledge, this is one of the first studies to contrast the capacity of rumination and reflection to predict variability in state anxiety when approaching a stressful situation. However, other studies using the RRQ have found that, in contrast to rumination, reflection is unrelated or inversely related to negative emotional

experiences such as depression (Jones, Papadakis, Hogan, & Strauman, 2009; Takano & Tanno, 2009), posttraumatic stress symptoms (Cann et al., 2011), and shame (Joireman, 2004). There is evidence that, under certain circumstances, reflection can be an effective emotion regulation strategy, which reduces social anxiety in the laboratory setting (Cristea, Matu, Szentagotai-Tatar, & David, 2013)

The results of the current study provide further empirical support for the theory advanced by Koster et al. (2011), which proposes that elevated ruminative disposition is characterized by impaired attentional disengagement from negative information, rather than by facilitated attentional engagement with negative information. The present findings parallel those of Grafton et al. (2016) who, using this type of attentional assessment task, observed that people who report heightened trait rumination display impaired attentional disengagement from depressogenic information, but not facilitated attentional engagement with such information. In addition to replicating this rumination-related attentional disengagement bias, our study extends the results of Grafton et al. (2016) by showing that this attentional effect is not restricted to depressogenic information, but is also evident on negative information related to an impending threat (i.e., exam-related words).

Our finding that pre-exam state anxiety was predicted by impaired attentional disengagement from, rather than facilitated attentional engagement with, exam-relevant negative information, suggests that the former pattern of attentional selectivity may play an especially important role in emotional responding to situational stress. There is evidence in the literature that people with heightened vulnerability to anxiety display difficulties disengaging attention from negative information (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006; Salemink, van den Hout, & Kindt, 2007), and also evidence that they display facilitated attentional engagement with negative information (Clarke, Hart, & MacLeod, 2014). Using a variant of the presently employed attentional probe task, Rudaizky, Basanovic, and MacLeod (2014) have demonstrated that elevated trait anxiety is characterized by both attentional engagement bias and attentional disengagement bias, but each of these two forms of attentional bias predicts independent variance in trait anxiety scores, permitting the possibility that they may be differentially implicated in stress responding. However, as Cisler and Koster (2010) have pointed out, there is a surprising lack of research assessing the degree to which these specific patterns of attentional selectivity predict self-reported distress. Our results indicate that it was difficulty disengaging attention from negative information that predicted state anxiety before the exam, and this association remained significant even after controlling for trait anxiety.

It remains to be seen whether attentional disengagement bias will always predict state anxiety responses to real world stressors better than attentional engagement bias, or whether this will depend upon the specific characteristics of the particular stressor. Plausibly, given its functional importance for their occupation role, exam-relevant information may engage the attention of all students, meaning that variability in their state anxiety levels during the pre-exam period might depend mainly on their capacity to periodically disengage from exam-related thinking. In other potentially stressful circumstances such as social situations, where there is less functional value in attending to mildly negative information (such as disapproving negative expressions), it may be the case that individual differences in the degree to which such negative information selectively captures attention makes a greater contribution to variation in state anxiety levels. Future research, employing variants of the present attentional assessment task, could now usefully investigate whether systematic differences between stressors serve to determine if

variability in the state anxiety they elicit is better predicted by biased attentional engagement with, or by biased attentional disengagement from, stressor-relevant negative information.

A major contribution of the present study is that it directly tested, for the first time, the hypothesis that the association between ruminative disposition and state anxiety experienced prior to a stressor is mediated by impaired attentional disengagement from negative information. Our findings were fully consistent with this hypothesis. Variation in attentional disengagement from exam-relevant negative information mediated the relationship between ruminative disposition and pre-exam state anxiety, regardless of whether or not trait anxiety was controlled for. Variation in attentional engagement with such negative information did not. This pattern of findings invites speculation that heighted ruminative disposition may drive this attentional disengagement bias, which in turn exerts an influence on emotional responding to stress. If so, it follows that rumination-linked patterns of excessive state anxiety in response to situational stress may potentially be alleviated not only by interventions designed to attenuate rumination itself (c.f. Querstret & Cropley, 2013), but also by interventions designed to directly attenuate this attentional bias (c.f. MacLeod & Clarke, 2015). Of course, the present study employed an association design, and so does not permit strong conclusions concerning the causal nature of the observed relationships between the variables of interest. Hence we recommend that future research seeks to directly manipulate rumination, to determine the resulting impact on attentional bias and state anxiety responses to stress, and to directly manipulate attentional disengagement bias, to determine the resulting impact on this state anxiety response and its association with rumination, in order to empirically establish the causal nature of the observed associations.

To conclude, our results indicate that ruminative disposition predicts state anxiety during a stressful pre-exam period; that heightened ruminative disposition predicts impaired attentional disengagement from exam-relevant negative information during this period; that this attentional disengagement bias predicts pre-exam state anxiety; and that this attentional bias mediates the observed relation between ruminative disposition and state anxiety levels prior to exam. In addition to confirming several findings recently reported in the literature concerning rumination and its attentional correlates, the current study provides new insight into the mediator role of attentional disengagement from negative information in the relation between ruminative disposition and state anxiety.

3.3. Study 3. The role of ego depletion and attentional bias in ruminative thinking and distress

Introduction

A provocative research area in the past two decades has been generated by the Strength Model of Self-control (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Vohs, & Tice, 2007). According to the model, self-regulatory efforts reduce strength and lead to self-regulatory fatigue frequently named *ego depletion* (Baumeister et al., 1998), which in turn decreases the ability to exert self-control on a following task. It has been suggested that, comparable to muscular activity, self-control cannot be effective used continuously without a resting period during which the resource is refueled (Baumeister et al., 2007).

To test the assumptions of this model, participants are evaluated in two consecutive tasks (Baumeister et al., 1998); the first aims to deplete cognitive resources, and the second, to show the effects of depletion. It was postulated that self-control involves effort and mental fatigue as a consequence of this effort (see Baumeister et al., 1998; Evans, Boggero, & Segerstrom, 2015). For instance, in a series of experiments Baumeister and colleagues (1998) showed that participants who were in a depletion condition (i.e., that aimed to trigger self-regulatory/self-control processes) generally performed worse in the second task compared to those who were in a control condition. However, it was proposed that some physiological underlying processes may be the fuel of self-control.

It has been proposed that blood glucose underlies self-control (Gailliot et al., 2007; Gailliot & Baumeister, 2007). Gailliot and Baumeister (2007) argued that blood glucose is the fuel for the brain, supporting neurons to fire impulses. According to these authors the majority of cerebral functions rely on blood glucose, but there are some cognitive resources that require more blood glucose. For instance, it was suggested that self-control is a complex executive mental process that requires more blood glucose than simpler processes (Gailliot & Baumeister, 2007). Additionally, self-control is sensitive to changes in blood glucose and seems to be impaired when the level of blood glucose is low (Gailliot & Baumeister, 2007).

In a series of experiments, Gailliot and colleagues (2007) demonstrated that participants engaging in a self-control task showed significant decreases of blood glucose. Furthermore, they found that the level of blood glucose after a first self-control task (e.g., emotion regulation) was related to a poor performance on a subsequent self-control task (e.g., solving anagrams). Moreover, new evidence points out that solving complex mental math exercises depletes limited self-regulatory resource and increases subjective fatigue of participants (Schmeichel, Vohs, & Baumeister, 2003). Although these results seem to be encouraging, there are numerous uncertainties about the role of blood glucose in self-control (for a meta-analysis see Dang, 2016). To avoid conceptual misunderstandings in present article we will refer to the blood glucose decreases as *depletion*.

According to Baumeister and colleagues, there is a link between emotion regulation strategies and self-control (Baumeister et al., 1998; Muraven, Tice, & Baumeister, 1998). Data concerning manipulation of emotion regulation - the actions undertaken by people in order to influence what type of emotion they feel, the moment of expressing emotion and the way in which these emotions are experienced or expressed (Gross, 1998) - showed that participants who were instructed to suppress emotions while watching 10 minutes of a sad movie had a poorer performance on a subsequent anagram task compared to a control group (Baumeister et al., 1998).

Furthermore, Grillon and colleagues showed that mental fatigue as a consequence of cognitive depletion plays an important role in the emotion processing and regulation (Grillon et al., 2015). Their results indicated that participants who were more fatigued following the engagement in a cognitive task reported deficits in emotion regulation compared to control (Grillon et al., 2015). However, given that the investigation of resource depletion on emotion regulation is in its early stages, more investigations in this direction are needed.

Moreover, Tice and Bratslavsky (2000) argued that emotions can create negative spirals suggesting that self-control may result in negative moods which in turn may lead people to fail in self-regulating. The aversiveness of emotional distress makes people change priorities in order to reduce the negative moods and feel better (Tice & Bratslavsky, 2000). However, in order to control and regulate their moods and the associated stress, people may engage in ineffective strategies (i.e., rumination) that can prolong the negative moods (Lyubomirsky & Nolen-Hoeksema, 1993; Tice & Bratslavsky, 2000).

According to the diathesis-stress model (Ingram & Luxton, 2005) stress activates vulnerabilities for development of psychological disorders. Among vulnerability factors involved, rumination was found to be an important risk factor for psychopathology (see Nolen-Hoeksema et al., 2008). As a response to distressing events, some people repeatedly focus on the negative aspects of emotions (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008) in order to better understand their causes and consequences and solve their problems (Costas Papageorgiou & Wells, 2003). Recent data indicate that there are two subcomponents of rumination: *brooding* and *pondering* (Treynor et al., 2003). Brooding is considered a maladaptive form of rumination, being closely related to negative affect, while pondering is considered an adaptive response to negative events and feelings (Treynor et al., 2003).

The most frequently used measure of rumination is the Ruminative Responses Scale (RRS; Nolen-Hoeksema, Larson, & Grayson, 1999) which assesses the general tendency of people to engage in rumination. However, some frequent critiques emphasize that this measure may be biased due to the retrospective thinking (Stone et al., 1998) and the impossibility of measuring rumination at the current moment. An alternative to this type of measurement is provided by studies that manipulate rumination in the laboratory in order to assess the immediate/natural consequences of rumination in response to a stressor (Nolen-Hoeksema et al., 2008). State rumination, has different properties than trait rumination (Moberly & Watkins, 2008a) predicting affective distress beyond trait measures. Moreover the instability of trait measures and the incapacity of surprising daily fluctuations of rumination underlie the relevance of using state rumination measures.

In line with Gailliot and collaborators' (2007) work, we aimed to analyze how depletion can influence state rumination and subjective distress as a response to negative feedback on a computerized task. To our knowledge, only one study (Rippere, 1984) has investigated the relationship between blood glucose and rumination. In her study, Rippere proposed that fluctuating blood glucose is responsible for obsessional thoughts or ruminations. She also suggested that an appropriate dietary and nutritional means should reduce ruminative thoughts. Although these data rely on two case studies, results seem to be promising. After changing dietary patterns both patients reported a reduction in severity of ruminative thoughts (Rippere, 1984). However, given the scarcity of data on the relation between blood glucose and rumination, future studies on this issue are needed.

Concerning the negative effects of rumination, it is necessary to find mechanisms that might be responsible for ruminative disposition. Some theoretical accounts proposed that

attentional bias to negative information might contribute to rumination (Koster, De Lissnyder, Derakshan, & De Raedt, 2011b). Using the traditional attentional probe task (C. MacLeod et al., 1986) relations between attentional biases toward negative information and rumination were confirmed, especially in dysphoric groups (e.g., Donaldson, Lam, & Mathews, 2007; Joormann, Dkane, & Gotlib, 2006). The assessment of the attention bias focuses on two independent indicators: engagement with stimuli and disengagement from them (Ben Grafton & MacLeod, 2013). A recent study aiming to assess these constructs in relation to rumination, showed that ruminative disposition is associated with impaired attentional disengagement from negative information, rather than facilitated attentional engagement with negative information (Ben Grafton, Southworth, Watkins, & MacLeod, 2016). However, attentional bias was mainly investigated in association with trait rumination and less with state rumination.

The present study had a number of goals concerning both the impact of induced cognitive depletion (assessed both subjectively – subjective fatigue and physiologically – blood glucose levels) on state rumination, subjective distress and related outcomes, as well as the associations between trait rumination and attentional engagement/disengagement biases (on one side) and state rumination and subjective stress (on the other). First, we hypothesized that the group for which depletion is induced through a difficult arithmetic task will have higher levels of state rumination and distress in a computerized task inducing social stress, when compared to the group for which depletion has not been induced. Second, we analyzed the relationship between attentional bias for negative stimuli (anxious and depressive), state rumination, and distress in a computerized task in which social stress is induced. Third, we investigated the relationship between trait and state rumination and distress in a computerized task in which social stress is induced.

Method

Participants

Participants were 85 (18% male) undergraduate psychology students from Babeș-Bolyai University of Cluj-Napoca. Participants' age ranged from 18-38 years (M =21.16, SD =4.58). Sixty five participants cover the entire protocol. All participants received credit course if they covered the entire protocol of the study. The study was approved by the Ethics Committee of Babeș-Bolyai University.

Procedure

The present study involved the following stages: (a) basement measures, (b) attentional task measure, and (c) experimental task.

Questionnaires

Two well-known measures of rumination were used. Ruminative Responses Scale (RRS, Nolen-Hoeksema & Morrow, 1991) was used to asses trait ruminative styles. The Rumination-Reflection Questionnaire *(RRQ,* Trapnell & Campbell, 1999) was used to assess the adaptive and maladaptive components of rumination. A more detailed description of these scales can be found in Study 2 (page 75). All scales showed good psychometric properties (Cronbach's alpha coefficient .92 and .87 respectively).

Attentional probe task

The attentional probe task was used to differentiate between attentional engagement with and disengagement from negative stimuli was similar to Grafton, Watkins, and MacLeod (2012), and Grafton, Southworth, Watkins, and MacLeod (2016). The same words stimuli as Grafton et al., (2016) were used. Therefore, 64 words stimuli were splitted according to their valence (positive

and negative words). Half of the negative/positive word stimuli were related to sad/happy and the other half to the anxious/relaxed domains. In the end there were 32 words related to sad/happy domain whereby 16 words were negative (sad related words) and the other 16 were positive (happy related words). The other 32 words were splitted the same manner, but words were related to anxious/relaxed domain.

The attentional probe task firstly anchored the participant's attention in either an upper and lower screen location. Next, they need to apprehend the orientation of an anchor probe. After that a word - non-word pair was presented. Finally, a target probe was presented in either the word or non-word location and participants were asked to determine if target probe orientation matches that of the anchor probe. The locus of word – non-word pair was systematically manipulated. Therefore, in some cases the word was be distally displayed relative to the initial attentional focus (attentional engagement bias assessment trials), in other cases the word would be proximal to the initial attentional focus (attentional disengagement bias assessment trials).

Each trial started with the 1,000 ms presentation of upper and lower string of asterisks that were presented in the most important screen regions. The asterisks were presented horizontally on the screen with 3 cm vertically distance. Between asterisks 5 arrows indicated either upper or lower screen location. Participants were instructed to direct their attention to the screen region indicated by the arrow direction. Next, an anchor probe (a 2 mm slash red line sloping oriented 45 degree either to the left or right) was briefly exposed (150 ms). Then, in the critical screen regions one word and one non-word were presented for 1,000 ms.. Finally, the target probe (a red line similar to the anchor probe) appeared. The location of the anchor probe was manipulated, appearing in either of the two screen regions with an equal probability. Participants were asked to indicate if the direction of target probe matches the direction of anchor probe, as quickly as possible. They needed to hit right click on the mouse if anchor and target probe were in the same direction, and left click if they were opposite. Subsequently, the screen was cleared for 1,000 ms before the next trial began. Each participant completed 256 trials in a random order, each letter string pair being presented for 4 times.

Computation of Engagement and Disengagement bias

All scores that were atypically low (i.e., outside the 95% confidence interval) were eliminated. Data from 15 participants were not included in the analysis due to the high error rates. Participants' latencies to correctly discriminate probes, we calculated following the suggestions of (Leys et al., 2013). Thus, probe discrimination latencies that fell further than 2.5 times the median absolute deviation from the participant's median reaction time (RT) under each experimental condition were eliminated. Finally, the participants' median probe for discrimination was calculated. In order to compute an index of engagement and disengagement bias these latency data were used.

The Engagement Bias Index reflects the degree of attention moved to the locus of negative information compared to positive information that was presented distally form the initial locus of attentional focus. This index was calculated using the following equation:

Engagement Bias Index = (Anchor probe distal to negative word in letter string pair : RT for target probe distal to negative word - RT for target probe proximal to negative word) - (Anchor Probe distal to positive word in letter string pair : RT for target probe distal to positive word - RT for target probe proximal to positive word).

The Disengagement Bias Index, reflects the degree of attention that was selectively held by negative information compared to positive information that was presented in the same locus as initial attentional focus. This index was calculated using the following equation:

Disengagement Bias Index = (Anchor probe proximal to negative word in letter string pair: RT for target probe distal to negative word - RT for target probe proximal to negative word) - (Anchor probe proximal to positive word in letter string pair : RT for target probe distal to positive word - RT for target probe proximal to positive word).

Blood glucose preparations

When participants were scheduled for the experimental sessions they were instructed to try to not eat anything before. In order to increase the accuracy of blood glucose assessment, all participants were scheduled for the laboratory session in the morning. Furthermore, after they arrived at the laboratory, they were asked to wash their hands and a researcher also cleaned their fingers with alcohol. The blood glucose level was measured using ACCU-CHEK Active Glucose Monitor.

Experimental session

A trained researcher told participants that the experimental session would consist of two parts: *a training session* and an *experimental task.* In the training session participants had to mentally solve some math exercises for 10 minutes. The difficulty level of math exercises were different depending on the group participants were randomized to: the control group received easy math exercises (e.g., 2 + 3) while the experimental group had to solve more difficult exercises (e.g., 54 + 68). The aim of the training task was to lead to cognitive depletion. We programmed the duration of training session to 10 minutes for each participant. When the correct answer was introduced the program automatically moved on to the next math exercise. All exercises were randomly presented across participants. Blood glucose level was measured before and after the training session.

Experimental task

The online experimental task was adapted after the Interpersonal Persistence Task used by Collins, Best, Stritzke, and Page, (2016). In our task participants were required to mentally solve more difficult math exercises (e.g., 23 * 4 + 56 – 21 =) than in the training session. Compared to training task, in this part, participants had to press Enter after introducing a result in order to move on to the next exercise. Participants were told that they are in a team with other two "co-players" who were in other rooms. To increase the plausibility of "co-players" three participants were invited to laboratory to run the task at the same time. At the end of each sequence of the task participants had the opportunity to communicate with the other "co-players". Participants were told that both individual and team performance are important. Participant's apparent task was to have a good individual score and to contribute as much as possible to the team's performance. The team's performance was allegedly compared with the average performance of other teams previously enrolled in the study. This represented the target score they were instructed to beat. Unlike in the Collins and colleagues task (2016), we separated the experimental task into three sequences, with a 3 minutes duration per sequence. Between sequences, both the individual's and the fake team's results appeared on the screen. In addition, a "fake" chat box appeared 15 seconds later, and participants were led to believe that they could use it to talk to their teammates. At the end of the chat, each participant saw the percent of his/her contribution to the total team's score.

Negative feedback manipulation

The negative feedback was delivered after each sequence via individual performance (won and lost points), team's performance (won and lost points of teammates), and the target score (which was always higher than the team's score). Furthermore, each participant clearly had the lowest score compared to the other team members. Finally, negative feedback was manipulated

using feedback statements. In order to blind the purpose and the study hypotheses, participants were encouraged to talk with their co-players in order to improve team performance. Once they send the message toward the "co-players" they received pre-generated statements such as ("Are you sure you're pressing the correct keys? ☺", or "You really did not like math…").

Following the third sequence, participants were give a 10-minute break, an interval that would allow them to ruminate about the negative feedback received. Subsequently, they filled in the rumination scales and three open ended questions that were designed to assess the credibility of the task and feedback ("Do you have any comments about the experiment?", "How would you rate your performance: a) *better* b) *at the same level* c) weaker than my teammates", and "How do you explain the performance differences between you and your colleagues?"). At debriefing participants were informed that the other players were not real and the messages were generated by the computer.

Post event rumination measure

In order to assess the post-event rumination we used a short form of the Thoughts Questionnaire (Edwards, Rapee, & Franklin, 2003). Participants had to respond on a scale ranging from 0 (*Never*) to 4 (*Very often*) how much they engaged in post event processing higher scores suggesting increasing in post-event processing. The scale contains three subscales: *negative rumination*, *positive rumination* and *general rumination.* Negative state rumination measure showed good psychometric properties (Cronbach's alpha coefficient was .87) while the positive and the general measure of state rumination had a poor internal consistency (Cronbach's alpha coefficient .42 and .48 respectively).

Perceived difficulty of the experiment was assessed using a Visual Analogue Scale (VAS) with responses ranging from 0 (not at all) to 10 (very difficult), higher scores indicating greater difficulty.

Subjective fatigue was assessed using a Visual Analogue Scale (VAS) with responses ranging from 0 (not at all) to 10 (very tired), higher scores indicating greater fatigue.

Subjective distress was assessed using a 7-point Likert scale with responses ranging from 0 (*relaxed*) to 7 (*stressed*). These measure was used to assess the level of distress after the experimental task.

Data analysis

According to National Institute for Clinical Excellence (NICE) a normal blood glucose for healthy individuals ranges between 72-108 mg/dL. Seven participants had values of blood glucose that were not in this interval, so they were not included in the analysis.

Five participants who reported that they did not believe the negative feedback on the laboratory rumination task were also excluded from data analysis.

Independent sample t-tests were used to analyze if there were group differences on the perceived difficulty of the experimental task, subjective fatigue, and depletion. The depletion score was computed as difference scores in blood glucose that were calculated by subtracting the level of blood glucose after the self-control task from the level of blood glucose before the task.

In order to investigate the moderation effect of the level of subjective fatigue on the impact of self-control task difficulty on depletion, participants were considered to have a high/low level of subjective fatigue if they scored 1 SD above/below the sample mean, and to have a medium level if they scored in the range of ± 1 SD from the mean. Subsequently a two-way analysis of variance (ANOVA) was computed testing the interaction effect between the self-control task difficulty and level of subjective fatigue on depletion.

In order to investigate the impact of the difficulty of the self-control task on state rumination and subjective distress, as well as the moderation effect of subjective fatigue, four two-way ANOVAs were run.

The association between trait rumination, state rumination (i.e., negative rumination, positive rumination and general measure of state rumination) and subjective distress were investigated using Pearson correlation.

The association between engagement and disengagement attentional bias to sad and anxious material, state rumination, and subjective stress were investigated using Pearson correlation.

Results

1. The relationship between ego depletion – rumination and distress.

Results showed that the perceived difficulty of self-control task was significantly greater in the experimental group as compared to the control group ($t(56) = -2.174$, $p < .05$). Results showed no significant differences on the subjective fatigue ($t(56) = -.984$, $p = .32$) and depletion ($t(56) = -259$, $p = .79$) between groups.

The moderation analysis that was run to assess if the impact of the self-control task on depletion is influenced by the subjective fatigue showed a significant interaction effect ($R2 = .08$, $F(1, 54) = 4.76$, $p = .033$). The analysis of regression slopes suggested that the type of self-control task significantly impacted on depletion only for the participants that reported high levels of subjective fatigue ($B = 4.40$, $t = 1.99$, $p = .051$, CI [-.024; 8.830]) with higher levels of depletion in the experimental group (see *Figure 1, 2, 3*). As it can be seen in *Figure 4* results concerning the association between subjective fatigue and depletion for each group indicate that a high level of subjective fatigue tends to be associated with a higher level of depletion only in the experimental group.

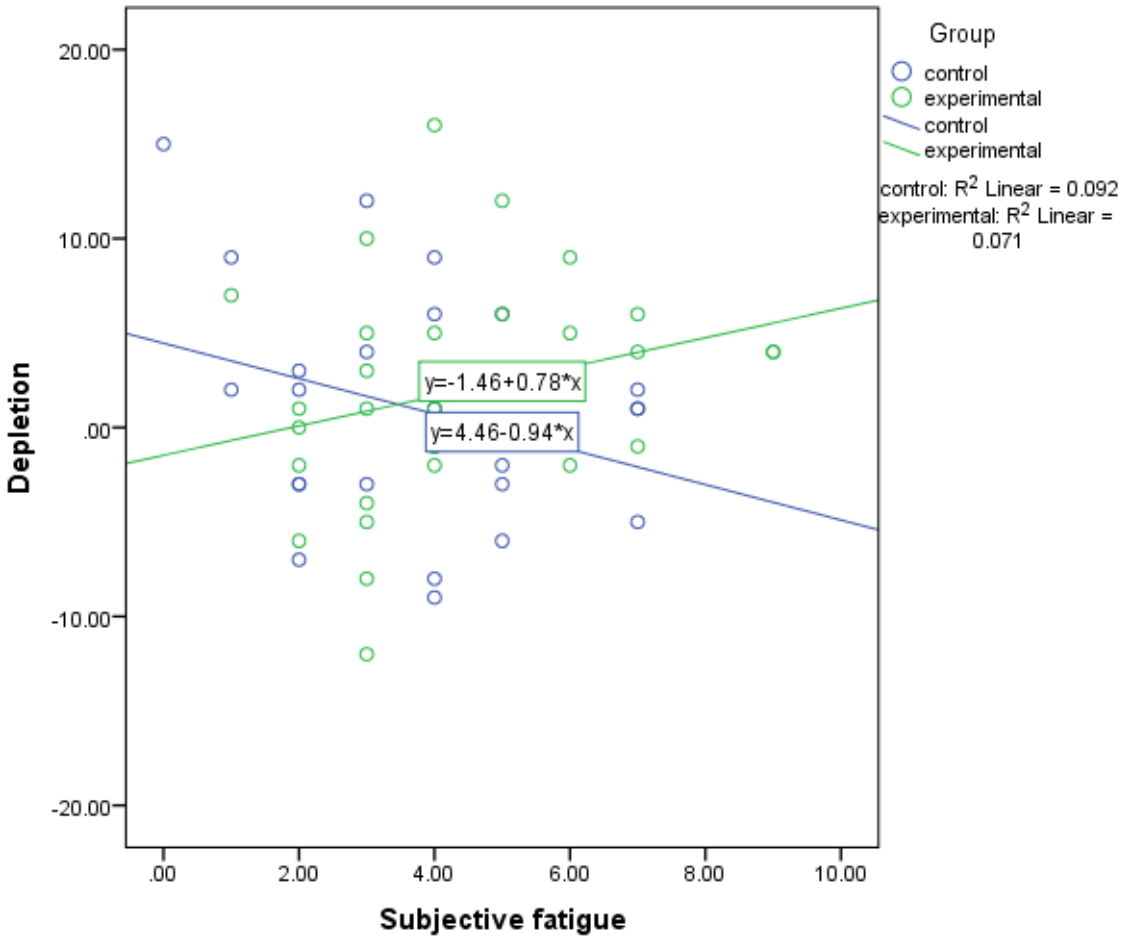

Figure 1. The association between subjective fatigue and depletion for each group.

Results of the first two-way ANOVA showed that neither task difficulty ($F(5, 53) = .566$. $p = .45$) nor level of subjective fatigue significantly impacted on the level of negative state rumination (F (5, 53) = .357, $p = .70$). The non-significant interaction between task difficulty and subjective fatigue indicated that subjective fatigue did not moderate the impact of task difficulty on negative state rumination ($F(5, 53) = 1.433$, $p = .24$).

The results of the second two-way ANOVA showed that task difficulty ($F(5, 53) = 4.255$. $p = .04$) significantly impacted on the level of positive state rumination. Results suggested that participants in the experimental condition had higher levels of positive rumination than those in control condition. However, the level of subjective fatigue did not impacted on the level of positive state rumination (F (5, 53) = 1.173, $p = .31$). The non-significant interaction between task difficulty and subjective fatigue indicated that subjective fatigue did not moderate the impact of task difficulty on positive state rumination ($F(5, 53) = .307$, $p = .74$).

The results of the third two-way ANOVA showed that neither task difficulty ($F(5, 53) = .219$. $p = .64$) nor level of subjective fatigue significantly impacted on the level of general state rumination (F (5, 53) = .853, $p = .43$). The non-significant interaction between task difficulty and subjective fatigue indicated that subjective fatigue did not moderate the impact of task difficulty on the general measure of state rumination ($F(5, 53) = .123$, $p = .88$).

The results of the fourth two-way ANOVA showed that neither task difficulty ($F(5, 53) = .039$. $p = .84$) nor level of subjective fatigue significantly impacted on the level of subjective distress (F (5, 53) = 3.445, $p = .14$). The non-significant interaction between task difficulty and subjective fatigue indicated that subjective fatigue did not moderate the impact of task difficulty on subjective distress ($F(5, 53) = .927$, $p = .40$).

2. The relationship between trait rumination – state rumination and distress.

Concerning the relationships between trait and state rumination, results indicated that both trait rumination (i.e., *RRS*) and the components of rumination (i.e., *brooding*, *depressive*) were associated with negative state rumination (see Table 1). In addition general ruminative disposition and depressive rumination were significantly positively associated with the general measure of state rumination.

As it can be seen in Table 1, brooding but no other measures of trait rumination were significantly associated with subjective distress after the experimental task. In addition, only negative state rumination was related to subjective distress. No other state rumination measure was significantly related with subjective distress (see Table 1).

3. The relationship between attentional bias – state rumination and distress

Concerning the relations between attentional engagement and disengagement bias with sad stimuli and state rumination, results showed that Engagement Bias scores for stimuli from the Sad/Happy domain were negatively associated only with the general measure of state rumination (see Table 1) and were not related to subjective distress. However, the Disengagement Bias scores for stimuli from the Sad/Happy domain were not associated with state rumination but were positively associated with subjective distress (see Table 1).

Regarding the relationships between attentional engagement and disengagement bias with anxious stimuli and state rumination, results showed that Engagement Bias scores for stimuli from the Anxious/Relaxed domain were not related with state/trait rumination and neither with subjective distress (see Table 2). However, Disengagement Bias scores with stimuli from the Anxious/Relaxed domain were negatively associated with negative state rumination and positively associated with positive state rumination (see Table 2). In addition, Disengagement bias scores for Anxious/Relaxed stimuli were negatively related to subjective distress (see Table 2).

Table 1
Associations between state/trait rumination, subjective stress, and attentional engagement and disengagement bias sadness stimuli

	ThQ - N	ThQ - P	ThQ - Gen	Stress	RRS	RRS - B	RRS - R	RRS - D	RRQ - B	RRQ – R	Eng bias sad/happy	Diseng bias sad/happy
ThQ – N	1.00	-0.09	.264*	.672**	.331**	-0.07	.213*	.249*	-0.08	.270*	-0.01	0.03
ThQ - P	-0.09	1.00	-0.18	-0.18	-0.01	0.03	-0.19	-0.03	-.231*	-0.19	0.02	-0.09
ThQ - Gen	.264*	-0.18	1.00	0.16	0.18	0.10	.279*	0.18	0.20	.283*	-.239*	-0.02
Stress	.672**	-0.18	0.16	1.00	.218*	0.05	0.15	.227*	0.00	0.15	0.08	.259*
RRS	.213*	-0.19	.279*	0.15	.493**	0.19	1.00	.845**	.682**	.955**	-.249*	-0.09
RRS - B	.249*	-0.03	0.18	.227*	.553**	0.11	.845**	1.00	.419**	.760**	-0.18	-0.07
RRS – R	-0.08	-.231*	0.20	0.00	0.12	.390**	.682**	.419**	1.00	.487**	-.264*	0.01
RRS – D	.270*	-0.19	.283*	0.15	.506**	0.10	.955**	.760**	.487**	1.00	-0.21	-0.11
RRQ - R	-0.07	0.03	0.10	0.05	0.04	1.00	0.19	0.11	.390**	0.10	-0.01	-0.01
RRQ - B	.331**	-0.01	0.18	.218*	1.00	0.04	.493**	.553**	0.12	.506**	-0.08	-0.11
Eng bias sad/happy	-0.01	0.02	-.239*	0.08	-0.08	-0.01	-.249*	-0.18	-.264*	-0.21	1.00	0.18
Diseng bias sad/happy	0.03	-0.09	-0.02	.259*	-0.11	-0.01	-0.09	-0.07	0.01	-0.11	0.18	1.00

Note: *. Correlation is significant at the 0.05 level, **. Correlation is significant at the 0.01 level (1-tailed). RRS - Ruminative Responses Scale, RRS-B- brooding subscale, RRS-D – depressive rumination subscale, RRS-R - reflection subscale, RRQ – Rumination Reflection Questionnaire, ThQ – N – Thought Questionnaire – negative state rumination, ThQ – P – positive state rumination, ThQ – Gen – general measure of state rumination.

Table 2
Associations between state/trait rumination, subjective stress, and attentional engagement and disengagement bias anxious stimuli

	Eng bias anxious/relaxed	Diseng bias anxious/relaxed	Stress	ThQ - N	ThQ - P	ThQ - Gen	RRQ - B	RRQ - R	RRS	RRS - B	RRS - R	RRS - D
Eng bias anxious/relaxed	1.00	.338**	-0.19	-0.19	0.01	0.07	0.09	0.16	0.03	0.01	0.07	0.01
Diseng bias anxious/relaxed	.338**	1.00	-.274*	-.235*	.254*	0.05	0.03	0.02	0.04	0.13	-0.02	0.02
Stress	-0.19	-.274*	1.00	.672**	-0.18	0.16	.218*	0.05	0.15	.227*	0.00	0.15
ThQ – N	-0.19	-.235*	.672**	1.00	-0.09	.264*	.331**	-0.07	.213*	.249*	-0.08	.270*
ThQ – P	0.01	.254*	-0.18	-0.09	1.00	-0.18	-0.01	0.03	-0.19	-0.03	-.231*	-0.19
ThQ – Gen	0.07	0.05	0.16	.264*	-0.18	1.00	0.18	0.10	.279*	0.18	0.20	.283*

RRQ – B	0.09	0.03	.218*	.331**	-0.01	0.18	1.00	0.04	.493**	.553**	0.12	.506**
RRQ – R	0.16	0.02	0.05	-0.07	0.03	0.10	0.04	1.00	0.19	0.11	.390**	0.10
RRS	0.03	0.04	0.15	.213*	-0.19	.279*	.493**	0.19	1.00	.845**	.682**	.955**
RRS - B	0.01	0.13	.227*	.249*	-0.03	0.18	.553**	0.11	.845**	1.00	.419**	.760**
RRS - R	0.07	-0.02	0.00	-0.08	-.231*	0.20	0.12	.390**	.682**	.419**	1.00	.487**
RRS - D	0.01	0.02	0.15	.270*	-0.19	.283*	.506**	0.10	.955**	.760**	.487**	1.00

Note: *. Correlation is significant at the 0.05 level, **. Correlation is significant at the 0.01 level (1-tailed). RRS - Ruminative Responses Scale, RRS-B- brooding subscale, RRS-D – depressive rumination subscale, RRS-R - reflection subscale, RRQ – Rumination Reflection Questionnaire, ThQ – N – Thought Questionnaire – negative state rumination, ThQ – P – positive state rumination, ThQ – Gen – general measure of state rumination.

Discussions

In the present research we aimed to investigate the assumptions of one of the most provocative theoretical accounts of self-control and its effects: the Strength Model of Self-Control proposed by Baumeister and colleagues (1998). It was suggested that all types of self-control depend on the same resource, and the consumption of these resources would lead people to an ego-depletion state (Baumeister et al., 1998). Blood glucose was hypothesized to be the physiological substrate of self-control resource (Dang, 2016). In this framework, we aimed to investigate the assumption that people who engage in a more difficult self-control task would be more depleted having reduced levels of blood glucose and fatigued than those who are involved in an easier self-control task. Concerning the fact that fluctuations in blood glucose would have an impact on state rumination and associated subjective distress, we aimed to explore the relationship between depletion and subjective fatigue (as a consequence of depletion), state rumination and subjective distress. State rumination and subjective distress were measured after the exposure to negative feedback in a computerized task. We also examined links between trait rumination and state rumination and subjective distress. Finally we investigated the relationships between attentional engagement and disengagement biases, state rumination and subjective distress.

1. The relationship ego depletion – rumination and distress

First we assessed whether there were differences between groups concerning depletion and subjective fatigue. Similarly we investigated if there were differences in the perceived difficulty of the self-control tasks between groups. We expected to detect higher levels on all three outcomes in the experimental group. Results of this study showed no significant differences between groups on blood glucose levels and subjective fatigue. The mean scores for subjective fatigue level, perceived difficulty of the task and the decrease of blood glucose were higher in the experimental group than in the control condition, but only perceived difficulty of the task was statistically significant. However, it seems that the impact of the self-control task on blood glucose is influenced by the subjective fatigue. The analysis of the regression slopes suggested that the decrease in blood glucose was higher in participants who reported a high level of subjective fatigue (+ 1 SD from the mean) only in the experimental group. This could indicate that future improvements of this study should address the self-control task we used in order to increase the subjective fatigue.

Further we investigated whether self-control task difficulty had an impact on state rumination and subjective distress. We also tested the influence of subjective fatigue on the magnitude/direction of this effect. We hypothesized that higher levels of state rumination and subjective fatigue would appear in the experimental group that received a more difficult self-control task. Results did not confirm our expectations indicating no significant influence of self-control task difficulty and subjective fatigue on negative state rumination and general measure of state rumination. However, task difficulty significantly impacted on the level of positive state rumination, but the level of subjective fatigue did not impact on the level of positive state rumination. These results are somewhat unexpected due to the fact that according to previous research (e.g., Rippere, 1984) it was expected for depletion to impact on negative state rumination and not on positive state rumination. However, future studies are necessary to further investigate these aspects. As mentioned, we were interested in testing how the interaction between task difficulty and subjective fatigue influenced state rumination. We found no significant interactions between task difficulty and subjective fatigue in any state rumination measures (i.e., negative, positive, general measure). These data may indicate that subjective fatigue was not a moderator in the relationship between depletion and state rumination. Future research on this issue is needed in order to explore what other factors can be responsible for the relations between depletion and state rumination.

Similarly, we sought to assess the impact of self-control task difficulty on subjective distress and to test whether subjective fatigue moderates this effect. We hypothesized that participants who received a more difficult self-control task would report higher levels of subjective distress. However, results indicated that that neither task difficulty nor level of subjective fatigue impacted on the level of subjective distress. In addition, the interaction between task difficulty and subjective fatigue was not significant. Furthermore, subjective fatigue did not moderate the impact of task difficulty on subjective distress.

2. The relationship between trait rumination – state rumination and distress.

Another goal of this study was to assess the relations between trait rumination, state rumination, and subjective distress. As we expected, we found a positive relationships between trait rumination and negative state rumination. Concerning the relations with subtypes of rumination, we found positive associations between brooding and both negative and the general measure of state rumination. This confirms the conceptualization of brooding as an maladaptive form of rumination (e.g., Treynor et al., 2003). Somehow surprisingly, participants who engage in positive rumination after the experiment tend to have lower levels of reflection, usually considered an adaptive form of rumination (e.g., Treynor et al., 2003). These data could suggest that there are differences between trait and state rumination measures and it is important to investigate both in experimental designs

Concerning the relationships with subjective distress, brooding but no other measures of trait rumination were significantly associated with subjective distress after the experimental task. Even though previous research found positive associations between both subtypes of rumination, brooding was found to be more strongly associated with perceived distress than reflection (e.g., Cole et al., 2015). In addition, in the present study only negative state rumination was related to subjective distress. No other state rumination measurements were significantly related with subjective distress. The association between state rumination and recovery from stress was demonstrated in previous research (e.g., LeMoult, Arditte, D'Avanzato, & Joormann, 2013). A valuable contribution of this study is that it explored the relation of both trait and state rumination with subjective distress. Moreover we also showed which type of state rumination (i.e., negative, positive or general state) might be more relevant to subjective distress after a difficult task. These data contribute to previous studies that showed relevant differences between trait and state rumination (i.e., Moberly & Watkins, 2008). Furthermore, these results could also underlie the importance of ecological measurements, showing that subjective distress might be a short term consequence of rumination. Still, based on the design of this study, a causal link between the two variables cannot be established.

3. The relationship between attentional bias – state rumination and distress

Finally, the last goal of this study was the investigation of the relationship between cognitive processes that would underlie trait and state rumination and subjective distress. In order to reduce the possible influence of attentional bias task on state measures, we assessed them at different time points. Results showed that Engagement Bias scores with stimuli from the Sad/Happy domain were negatively associated only with the general measure of state rumination and were not related to subjective distress. These results indicate that participants who had a lower level of general state rumination tended to selectively focus their attention to the locus of the sad stimuli compared to the happy stimuli. Again this is contrary to our expectation. On the other hand, attentional disengagement bias was not related to state rumination. However, we found that the extent to which attention was selectively held by the sad stimuli compared to happy stimuli was positively related to subjective distress. Our results also show that Engagement Bias scores with stimuli from the Anxious/Relaxed domain were

not related with state/trait rumination and neither with subjective distress. Disengagement Bias scores with stimuli from the Anxious/Relaxed domain, instead, were not associated with trait rumination measures but were negatively associated with negative state rumination and positively associated with positive state rumination. These results indicated that participants with a lower level of negative state rumination selectively directed their attention to anxious information compared to relaxed information. Furthermore, we found that the extent to which attention was selectively held by the anxious stimuli compared to relaxed stimuli was negatively related to subjective distress.

Although, some of these findings are in contradiction with previous studies showing that state rumination is related with attentional disengagement from sad stimuli (Ben Grafton et al., 2016; LeMoult et al., 2013), they are in accord with the results of other studies which found no evidence for a disengagement bias effect on brooding or reflective rumination (Ben Grafton et al., 2016).

Several limitations of the present research should be considered. One limitation is related to the small sample size that resulted in a reduced statistical power, as well as in less reliable (i.e., stable) results. Even though our hypothesis was not confirmed, we found that drops in blood glucose levels tended to be higher in participants in the experimental group who were more fatigued. However, these trends should been interpreted with caution due to the low number of participants (eight participants) who reported high levels of subjective fatigue. A frequent critique of studies that investigate depletion is related to high effect sizes reported in very small samples (see Dang, 2016). Future investigations of depletion in larger samples of participants using tasks that lead to higher levels of subjective fatigue are needed. The second limitation concerns the psychometric properties of state rumination measures. We explored relationships between state rumination measures and the other constructs according to the study objectives, but the results are difficult to interpret due to the poor internal consistency estimates obtained for two of the measures of state rumination (positive and general measure) in our sample. This suggests that results need to be interpreted cautiously and could also explain some of the surprising results we found (e.g., negative relationships between reflection and positive state rumination). An important limitation may be the investigation of the relationships of trait and state rumination and subjective distress with attentional engagement/disengagement bias using a correlational approach. This approach does not allow causal conclusions on the relations between the investigated factors. In addition, the nonclinical sample may be another limitation. Further investigations in clinical samples are needed.

However, in spite of these limitations, the present research has some important contributions. Our findings provide further support for investigating depletion and possible related consequences (i.e., as rumination). Moreover, they extend the literature on the possible mechanisms (i.e., attentional biases) that may lead to state rumination. To our knowledge, this is the first study to investigate relationships between ego depletion and state and trait rumination and subjective distress using an experimental design. Demonstrating the existence of relations between these constructs would clearly have important clinical contributions offering directions for prevention programs aimed at reducing affective disorders related to rumination (i.e., depression, anxiety).

Moreover, from a practical perspective this study tried to improve the ecological validity of rumination measures. Due to the spontaneous nature of rumination in everyday life (Genet & Siemer, 2012) we tried to not rely only on trait measures of rumination. Using state rumination has the potential to clarify (a) how psychological recovery occurs and (b) to indicate the presence of other factors which may lead to rumination, particularly after a negative/stressful event.

Furthermore, another valuable contribution is related to the computerized game we used to expose participants to negative feedback and to induce state rumination. Using this game, we addressed the human errors inherent to giving negative feedback and we increased chances for a successful manipulation. Negative feedback was given through two modalities: (a) personal results and contribution to the total score of the team and (b) interpersonal feedback statements. Moreover, this modality was quite effective in providing negative feedback, as suggested by the small number of participants who did not believe the feedback.

To conclude, the present findings contribute to the body of data regarding the relation between depletion, on the one hand, and rumination (trait and state) and subjective distress, on the other hand. In addition, this study provides support for the relation between attentional engagement/disengagement biases and (state and trait) rumination and subjective distress. Although, the results did not confirm our hypotheses, they can give new insight into investigating the depletion-rumination relation. Furthermore, assessing the associations between attentional engagement/disengagement biases and (state and trait) rumination and subjective distress may be useful in understanding factors responsible for ruminative responses.

3.4. Study 4. Cognitive bias modification for interpretation training in reducing state rumination

Introduction

Cognitive theories proposed that the way a situation is interpreted may be responsible for the development of emotional disorders (Beck, 1967). The cognitive biases in interpretation represent the tendency to erroneous interpret an ambiguous situation in a negative manner impairing the emotional regulation and increasing the vulnerability for disorder development (Joormann, Yoon, & Siemer, 2010). Everyday experiences offer us multiple situations when information can be easily interpreted in numerous ways. Interpreting a remark of your boss as dissatisfaction about your work, can generate different mood than attributing his remark to some health problems that his is dealing with. A number of studies proposed that negative self-beliefs and the reinforcement of negative memory biases are the main mechanisms through which interpretations maintain negative mood (Hertel, Brozovich, Joormann, & Gotlib, 2008). Biased interpretations were associated with anxiety (e.g. Hirsch & Mathews, 2000) but also with depressive symptoms (e.g. Hertel & El-Messidi, 2006). These studies demonstrated that individuals who were socially anxious, had the tendency to select the anxious interpretation after reading an ambiguous text scenario (for a review see Hertel & Mathews, 2011). Similarly, depressive individuals chose a negative interpretation (for a review, see Mathews & MacLeod, 2005). Furthermore, it was proposed that interpretation bias is the mechanism that encourages the act of repetitively thinking about owe's problems in individuals with emotional disorders (Hertel, Mor, Ferrari, Hunt, & Agrawal, 2014).

The act of repetitive (negative) thinking about one's problems and the cognitive and emotional consequences of this problems was called rumination (Nolen-Hoeksema & Morrow, 1991). Rumination is considered a transdiagnostic factor in psychopathology (Nolen-Hoeksema & Watkins, 2011) being involved in the development and maintenance of numerous affective disorders, especially in anxiety and depression (for a review, see Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Initially rumination was conceptualized as a unitary construct, but later analysis revealed the presence of two subtypes: brooding and reflection (Treynor, Gonzalez, & Nolen-Hoeksema, 2003). Brooding was defined as "*a passive comparison of one's current situation with some unachieved standard*" and was more frequently associated with psychopathology (i.e., *depression*, Nolen-Hoeksema et al., 2008), whereas reflection was defined as "*a purposeful turning inward to engage in cognitive problem-solving to alleviate one's depressive symptoms*" (Treynor et al., 2003, p. 256). When we ruminate, negative content becomes more accessible and it is maintained by cognitive biases (Nolen-Hoeksema et al., 2008). The first studies investigating cognitive biases in ruminators used attention and memory tasks. For instance, Daches and colleagues (2010) found that rumination is related to impaired attentional control in a task with self-relevant material. Similarly, Moulds, Kandris, and Williams (2007) showed that ruminators recalled more negative self-referential words than non-ruminators in a study that examined the impact of rumination on encoding information. However, recently it was suggested that another cognitive bias may be responsible for increasing ruminative thoughts.

Knowing the negative effects of rumination, cognitive researchers tried to understand the determinants of rumination, and how it can be reduced. It was proposed that making a negative interpretation to an ambiguous situation will increase the rumination tendency especially after the situation is disambiguated. As a consequence, this can encourage the vicious cycle of rumination and negative mood (Nolen-Hoeksema et al., 2008). Furthermore,

one recent computerized cognitive bias modification (CBM) technique aimed to modify interpretations (CBM - I) showed promising results in effectively reducing anxious moods or anxiety vulnerability (e.g., Andrew Mathews, Ridgeway, Cook, & Yiend, 2007) and the risk for depression (e.g. Dearing & Gotlib, 2009). In the CBM-I training, participants receive ambiguous homographs and are asked to complete a word fragment in a positive or a negative manner. Those who practice negative solutions reported feeling more anxious and made more negative interpretations of the novel test descriptions (Mathews & Mackintosh, 2000). Considering the important role of rumination in anxiety and depression, modifying the interpretation biases that lead to ruminative thoughts, would have numerous clinical implications. To our knowledge, there are two studies that targeted negative interpretations in ambiguous situations as possible causes of rumination.

A study conducted by Mor and colleagues (2014) found that ruminators tend to interpret ambiguous information in a rumination consistent manner. In both experiments, overall rumination and subtypes were associated with faster response time for ruminative targets than benign meanings of words (Mor et al., 2014). The study conducted by Hertel and colleagues (2014) aimed to investigate the cognitive bases of rumination in a task requiring to completion of a word fragment of an ambiguous scenario. Their results revealed that high ruminators resolved negative word fragments faster than low ruminators resolved the benign fragments. In the second experiment, Hertel and colleagues (2014) trained the interpretation bias in order to investigate the contribution to rumination. After training, those who were negatively trained continued to make negative interpretations in new subsequent tasks. Furthermore, negative interpretation training affected negative intrusions in memory and state rumination. These data offer us a good framework for the (causal) relationship between rumination and interpretation biases. However, extending this area of research to investigate how interpretation biases can affect habitual rumination in the context of other disorders (i.e. social anxiety) or how CBM-I training may influence rumination using an ecological measure of rumination, would clearly have important clinical implications.

In the present study, we aimed to investigate the effects of CBM-I training on daily rumination in a general population sample. Several investigators confirmed the rumination – social anxiety relationship (e.g., Abbott & Rapee, 2004) proposing that rumination includes both self or other-related evaluations (Kashdan & Roberts, 2007) before and after the social event (e.g., Clark & Wells, 1995; Vassilopoulos, 2004). Additionally, in light of previous results demonstrating that both socially and non-anxious volunteers have change the anxious mood after interpretational biases were experimentally manipulated (Mathews & Mackintosh, 2000), we assessed the training of negative interpretation of ambiguity as a potential source of rumination. Compared to Hertel and colleagues (2014) who used scenarios which can be resolved in both socially anxious and ruminative direction, we chose to use the socially anxious scenarios (which were initially used by Mathews and Mackintosh, 2000) aiming to assess how biased socially anxious interpretations can influence daily rumination. Considering that we intended to assess rumination on a daily basis, we decided to target socially-anxious scenarios due to the fact that negative social situations are more frequently encountered in real life settings. For instance, there is an extensive evidence showing that rumination as a response to daily life events (i.e., distressing social events), increases and prolongs negative moods in both clinically and healthy participants (e.g., Broderick, 2005; Genet & Siemer, 2012; Kocovski & Rector, 2007; Park, Goodyer, & Teasdale, 2004). The daily diary approach we used was the same as used by Genet and Siemer (2012). We consider that using a daily approach to study rumination will address the most problematic issues of traditional measurement methods. For instance, it is unclear if instructed rumination effects (in laboratory studies) remains generalized in everyday life (Genet & Siemer, 2012). Also, trait measures cannot capture the

fluctuations in state rumination and the effects of rumination across different negative life events (Genet & Siemer, 2012). However, the daily diary approaches of assessing rumination addresses these limitations (Shiffman, Stone, & Hufford, 2008).

The aim of this study is to investigate the effects of a CBM-I training on state rumination. Participants had to complete daily diary measures (state rumination, unpleasant event, and mood) for six times in two weeks. At the end of the first week, they received a CBM-I training (either positive or negative) and continued to complete the diary measures until the end of second week. We hypothesized that those who were positively trained compared to negatively trained will have lower levels of state rumination, and will have less negative moods after unpleasant events.

Method

Overview

The present study used a daily diary approach similar to Genet and Siemer (2012) in order to investigate the how daily rumination may be influenced by training biases in interpretation. Participants were scheduled to attend the training of interpretation in weekends. During the week they were scheduled and the week after, participants had to complete for three times per week the diary measures. At the end they had to complete the final questionnaires.

Participants

Participants, students in the first year of study, were recruited from Faculty of Psychology, Cluj-Napoca. Sixty undergraduates psychology students registered to participate in the current study. Forty six participants attend the training and completed the diary questionnaire and only forty three have fully completed the pre-post questionnaires. Participants who completed the entire protocol of the study were rewarded with course credit.

Measures

Initial Self-Report Measures

Ruminative Response Scale (RRS, Nolen-Hoeksema & Morrow, 1991; *The Rumination-Reflection Questionnaire* (RRQ, Trapnell & Campbell, 1999) and *Liebowitz Social Anxiety Scale* (LSAS, Liebowitz, 1987) and *Positive and Negative Affect Schedule* (PANAS, Watson & Clark, 1999) were administered. All scales show good psychometric properties.

Diary Measures

Unpleasant event and rumination questions.

Respondents were asked to think about the most negative event that happened during the day. They were instructed to rate how unpleasant the negative event was on a nine-point scale (1 = *not at all*, 9 = *extremely*). As Genet and Siemer (2012) mentioned, thinking about the most negative event would provide an accurate measure of state rumination, due to the tendency to ruminate about an event of a particular day and because can highlight the repetitive nature of rumination. Using a nine-point scale (1 = *not at all*, 9 = *extremely*) participants were asked to respond to six questions modified from Ruminative Response Scale (RRS: NolenHoeksema & Morrow, 1991). The six questions were taken from the study reported by Genet and Siemer (2012). An example of question is “I couldn’t stop thinking about how I was feeling”.

Training materials

The training materials were taken from the previous experiments of Mathews and Mackintosh (2000). Participants were scheduled into the laboratory in weekend for the training session. The laboratory session was divided into three parts: a) *training,* b) *presentation of ambiguous items* and c) *recognition test.*

Training

The training session involved reading a text fragment, with three sentences and finding a missing letter from a word that appeared at the end of text fragment. Each text fragment had only one possible solution. The word was either positive or negative depending on the direction of training. Below is an example of training item:

"Whilst shopping, you buy a new jacket on the spur of the moment. When trying
\it on at home, you decide that you do not really like it that much and take
\it back to the shop. The assistant gives you a refund and her attitude is:
Either rel-c---t (reluctant)
or co-p-----ve (cooperative)."

After that, participants had to answer with "yes" or "no" to a comprehension question. The aim of using this question was to assess if participants were concentrated on the meaning of the text and to reinforce the valence of the completed word. For the previous example, the comprehension question was: "Was the assistant agreeable when you asked for a refund". Those who were negatively trained were encouraged, through a feedback slide, to respond with "yes", while those who were positively trained to respond with "no".

The training part consisted of 130 training items, presented in 10 blocks of 13 items. In each block, the first 2 items were the same irrespective of direction of training. These probe items were fixed, one positive and one negative in outcome. Mathews and Mackintosh (2000) suggested that probe items are necessary in order to track the time of induced training effects. The next 8 items were valenced in line with the direction of training (positive or negative). The last three items, were fillers and were the same in both training groups. Between training blocks, participants had the option to rest. After the training phase end, participants continued with the test phase which had two parts: *presentation of ambiguous items* and *recognition test.*

Presentation of ambiguous items

Participants were exposed to 20 different ambiguous items which were presented in a similar form as in training. In this part, participants had to read a text fragment describing an ambiguous social scenario. However, the word fragment completion and the comprehension question maintained the ambiguity of text, encouraging participants' own interpretation of the text meaning. Each scenario has a title that was presented in the recognition test phase. An example of ambiguous item is:

"The bus ride
\You get on a bus and find an empty seat, next to one that has a small
\rip in it. At the next stop several people get on who know you, but all
\of them go and sit somewhere else so the seat next to you remains
v a - - - t (v a c a n t)".

The comprehension question for this item was: "Were the people who got on strangers to you?".

Recognition test

In this part of the experiment, participants received the title of ambiguous scenarios and some separate sentences for rating. For each title participants received four separate questions. Two sentences were target sentences matching the positive and the negative meanings of the text. These sentences allowed to assess their interpretation of the previous text. The other two sentences were foils, and did not match the text. One had a more positive interpretation and the other one had a more negative interpretation. The foils allowed to assess the wider valence priming effects of training (Mathews & Mackintosh, 2000). Below we present an example of these sentences:

"The bus ride
No one can sit next to you because the seat has a rip in it. (positive target)
No one chooses to sit with you so the seat next to you stays empty. (negative target)
The person in the seat next to you talks to you in a friendly way. (positive foil)

The person in the seat next to you makes a rip in the fabric." (negative foil)

The training sessions were presented on a computer with a monitor display of 24" using OpenSesame software (Mathôt, Schreij, & Theeuwes, 2012). Each participant was tested individually.

Procedure

Participants who enroll to participate in the present study completed RRS, RRQ, and LSAS questionnaire and gave a written consent. The consent specified that the study will take place over a 2-week period.

Diary measures before training

Participants could start to complete diary measures only if they were scheduled in weekend for the training session. In the week before training participants need to complete the diary measures (PANAS-X, unpleasantness, and rumination) for three times. Data from diary measures were collected online, using Google Forms. The link for measures was send through SMS in the day they need to complete it. The time needed to complete diary measures was under 5 minutes per day.

Training

The weekend after completing the diary measures, participants arrived to the laboratory and were randomly assigned to either a positive or negative training condition. They were instructed to read each sentence and to imagine themselves in the scenario and to try to find the significance of the word fragment. The scenarios were presented sequentially a line at a time and they had 10s to read it and to solve the word fragment. Once participants had identified the significance of the word fragment, they pressed space, and then the first letter that was missing from the word fragment. If the correct letter was pressed, the correct word was presented on the screen. The comprehension question then appeared for 10s. That was aimed to assess the understanding of the fragment text. Depending on training condition, feedback was provided after each answer. Reaction times and accuracy were registered for each item.

Following training, participants had to complete the 20 ambiguous test items that were similar to training except that these items had a title assigned. Participants were not instructed to memorize the title of the description, which would be tested in the recognition test. Test scenarios were randomly presented across participants.

Following the ambiguous items, participants had to complete the recognition test. They were given the title of the scenario and four questions and were asked to rate them according to the similarity in meaning with the original text (1 = *very different in meaning* to 4 = *very similar in meaning*). Two sentences were targets (positive and negative) and the other were foils (positive and negative). All sentences were presented independently, and the order of scenarios was random across participants.

Diary measures after training and final questionnaires

In the second week following training session, participants were instructed to complete the diary measures for another three times. Similar to the first week, the experimenter send the link with the measures through SMS to each participant in the day they need to complete it. Following the last session of the diary measures, participants received through SMS the link for the final questionnaires (RRS, RRQ, and LSAS). To encourage participants to complete the final questionnaires they were told that the link was available for only 72 hours. Table 1 presents the descriptive data from participants in the present study.

Table 1

Demographic characteristics, Pre-Post measures, Recognition test ratings

Measure	Positively trained (n = 22)	Negatively trained (n = 24)
Gender (male/female)	4/18	3/21
Age	22.77 (1.16)	24.37 (1.62)
RRQ_B 1	39.77 (2.04	41.25 (1.91)
RRQ_R 1	46.04 (1.58)	44.50 (1.32)
RRS 1	40.45 (3.00)	43.66 (2.78)
LSAS 1	47.22 (5.73)	45.04 (4.52)
Positive target	3.14 (0.29)	3.12 (0.07)
Negative target	2.83 (0.40)	2.74 (0.09)
Positive foil	2.32 (0.89)	2.31 (0.08)
Negative foil	1.70 (0.07)	1.82 (0.06)
RRQ_B 2	40.76 (2.04)	40.86 (2.36)
RRQ_R 2	47.95 (1.67)	43.54 (1.75)
RRS 2	42.85 (3.16)	42.13 (3.15)
LSAS 2	48.95 (6.50)	42.77 (5.42)

Note: LSAS- Liebowitz Social Anxiety Scale; RRS- Ruminative Response Scale; Rumination-Reflection Questionnaire (RRQ).

Results

Probe latencies

In order to assess the efficacy of training, reaction times to complete word-fragments on the fixed probes were analyzed. Each participant has an average score for first and second half (for negative and positive probes separately). For the calculation of means all incorrect responses, (pressing an incorrect letter for word completion) were omitted. After the correction of data distribution using the logarithmic transformation, the means were entered into a mixed model repeated measures ANOVA. Training group (positive trained, negative trained) was entered as between-subjects factor and probe valence (positive item, negative item) and half (first half, second half) as within-subjects factor.

A Training group x Valence interaction, $F(1, 43) = 5.04$, $p = .29$ partial $\eta^2 = .02$ was not significant. This suggest that trained people did not resolve faster the positive/negative fragments according to their condition.

The interaction of Training group x Valence x Half was also not significant, $F(1, 43) = .05$, $p = .81$ partial $\eta^2 = .23$. Furthermore, neither Group x Half interaction ($F(1, 43) = 5.29$, $p = .47$, partial $\eta^2 = .01$) was significant. However, mean comparisons showed that those who were negatively trained had slower reaction times from first to second half for positive probes (1114.85ms vs 468.24ms). Similarly, those who were positively trained had slower reaction times for negative probes from first to second half (787.63ms vs 538.09ms).

Recognition tests ratings

In order to examine the effects of training, participants had to recognize and rate (from 1 to 4) final sentences of the test scenarios. This was the principal measure of training effects. For each participant average score was obtained across the four conditions: negative target,

positive target, negative foil, and positive foil. In order to test the interaction, a three way mixed ANOVA with Training group (negatively and positively trained) as a between-subjects factor, and Target (target sentence, foil sentence) and Valence (positive and negative sentence) as within-subjects factor was run. The three-way interaction Training group x Target x Valence failed to reach significance $F(1, 44) = .16$, $p = .69$ partial $\eta^2 = .004$. Furthermore, neither the general effect of training was significant due to the Training group x Valence interaction, which was not significant, $F(1, 43) = .06$, $p = .80$ partial $\eta^2 = .001$. In addition, an independent t test was run in order to find if there were performance differences in selecting item according to their condition. However, results revealed no significant differences between groups in identifying nor negative items (positively trained group, $M = 2.27$, $SD = .30$, negatively trained group $M = 2.28$, $SD = .20$, $t(44) = .103$, $p = 13$, one tailed) neither positive items (positively trained group, $M = 2.27$, $SD = .30$, negatively trained group $M = 2.28$, $SD = .20$, $t(44) = -.09$, $p = 13$, one tailed). However, results showed large main effect of Target $F(1, 44) = 167.54$, $p < .001$, partial $\eta^2 = .79$, and of Valence $F(1, 44) = 35.74$, $p < .001$, partial $\eta^2 = .44$, suggesting that targets were given higher recognition ratings than foils, and positively sentences were endorsed higher than negative sentences.

Daily rumination

Rumination data from participants who did not confront with a negative event were not included in analysis.

A two-way repeated measure ANOVA was run in order to examine the effect of training over time on state rumination. Data Analysis of the studentized residuals showed that there was normality, as assessed by the Shapiro-Wilk test of normality and no outliers. There was sphericity for the interaction term, as assessed by Mauchly's test of sphericity ($p > .05$). However, there was not a significant interaction between training groups and time on state rumination $F(5, 170) = .592$, $p = .70$, partial $\eta^2 = .017$. The main effect of time showed that there was not a statistically significant difference in state rumination between time points, $F(5, 170) = 1.64$, $p = .15$. Figure 1 presents the variations of state rumination across time in both groups.

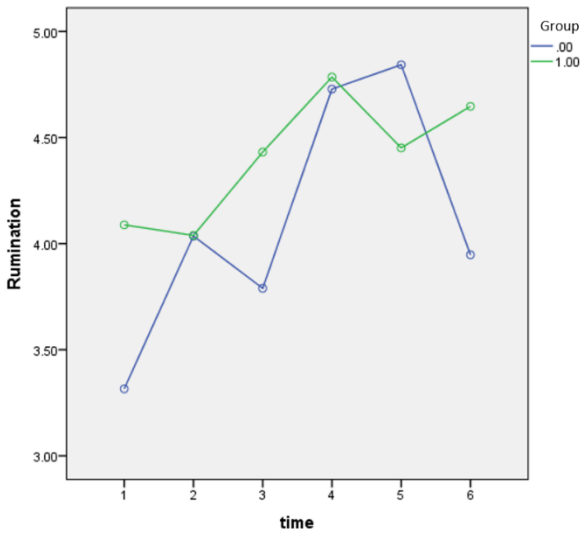

Figure 1. Group x Time x State Rumination interaction

State Rumination x Unpleasantness x Mood interaction

In a mixed model repeated measures ANOVA training Group (positive trained, negative trained) was entered as between-subjects factor and Diary measures (rumination, unpleasantness of the negative event and mood) and Time were entered as within-subjects

factors. There were no outliers, as assessed by examination of studentized residuals for values greater than ±3. Mauchly's test of sphericity indicated that the assumption of sphericity was met for the three-way interaction, $\chi^2(14) = 21.711$, p = .086. The three-way interaction between Group x Diary measures x Time, $F(10, 340) = 505$, $p = .886$ was not a significant (Figure 2 and Figure 3). In addition, there was neither a significant two-way interaction between Diary measures x Group $F(2, 68) = .779$, $p = .463$, nor between Time x Group interaction $F(5, 170) = 1.008$, $p = .415$.

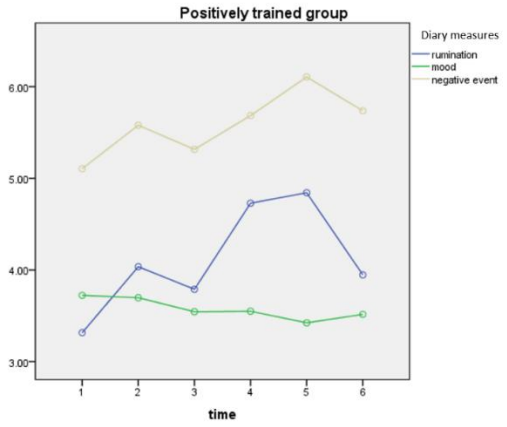

Figure 2. Diary measures on positively trained group

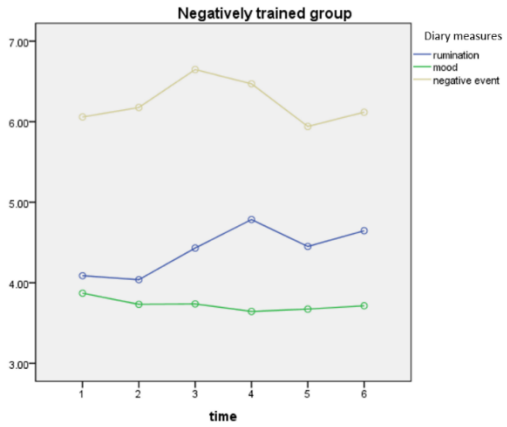

Figure 3. Diary measures on negatively trained group

Training effects over trait rumination and social anxiety

Our hypothesis was that the training will influence rumination and social anxiety symptoms. In a two-way ANOVA repeated measures the effects of training over time on rumination and social anxiety were tested. As expected, based on previous obtained results, there was not a significant interaction between training and rumination (measured with RRS) $F(1, 41) = 1.554$, $p = .22$, partial $\eta^2 = .037$. Furthermore, similar results were obtained when the same interaction was tested with the other rumination scale (RRQ) $F(1, 41) = .003$, $p = .96$, partial $\eta^2 = .000$. Finally, the effects of training did not differ over time depending on training $F(1, 41) = .159$, $p = .69$, partial $\eta^2 = .004$.

Discussions

The present study aimed to assess the effect of the CBM-I training on state rumination. Using an approach similar to Genet and Siemer, (2012) participants were instructed to keep a diary of negative events and take notes on how much they ruminated about these events over a two weeks period. At the end of the first week, participants were invited in laboratory to run the CBM-I training tasks. They were randomly assigned to positive and negative training conditions. Subsequently to the training session, participants continued to keep the diary until the end of the second week. Pearson correlations indicated significant associations between social anxiety, trait rumination and state rumination but only at some time points The only significant relationships between interpretation biases and state rumination were found in the positively trained group (i.e. between positive target and state rumination at time point 5, and between positive foil and state rumination at time point 4).

Results showed the inefficacy of the training, negatively trained participants scoring higher positive (targets) interpretations in ambiguous situations than those positively trained. Furthermore, the three-way interaction between training group, target and valence failed to

reach the significance. Similar results were obtained when we tested the general effect of training, the training group and valence interaction. Moreover, these CBM-I training did not influence daily rumination.

However, before drawing conclusions from this data, we found that it would be important to take into consideration the validity and reliability of present results. There are several features of this study supporting its validity. First important aspect is that all participants were randomly assigned to either positively or negatively trained group. Second aspect is that the training task we used was effective in previous other studies (e.g., Mathews & Mackintosh, 2000; Andrew Mathews, Ridgeway, Cook, & Yiend, 2007). Third, diary approach to measure rumination was also proven to be effective (e.g., Genet & Siemer, 2012). Fourth, we used an active control group to better control for the changes in experimental group (Boot, Simons, Stothart, & Stutts, 2013).

Some explanations may account for the absence of CBM-I training effects. *First*, it is about the relevance and the content of scenarios used. In this study the trained participants did not select the interpretations according to their training condition, in the recognition tasks. This might be due to the fact that we did not match the content of training with personal relevance particularly for those instructed to complete a negative meaning of the final word. It was also suggested that content of training need to match the intended target of change (Mackintosh, Mathews, Eckien, & Hoppitt, 2013). Moreover, it was also suggested that benign CBM-I effects on daily-life stressors would be more effective especially if training includes emotional challenges in order to activate the manipulated cognitive mechanism (Menne-Lothmann et al., 2014). We chose to not modify the original scenarios (used by Mathews and Mackintosh, 2000) because we believed that the numerous reasons causing daily rumination are related to social situations. Based on results from previous studies participants induced to negative and positive bias using modified scenarios transfer biases to solve subsequent ambiguous scenarios (Hertel et al., 2014). However, Hertel and colleagues (2014) failed to found evidence of effects between benign and control group. As authors suggested, using a ruminative scenario may be counterbalanced by the benign meaning of the final word. However, these affirmation may be applied to our study, explaining the lack of transferring interpretation bias.

Second, using a repeated number of training sessions would probably increase the training effectiveness. The results of a recent meta-analysis found that adding just one training session increased the effect size of the effect in both positive and negative interpretation bias (Menne-Lothmann et al., 2014).

Third, some procedural factors were found to influence the training effectiveness. Although, Mathews and Mackintosh (2000) used imagery instructions ("imagine yourself in the situation"), and we used the same method, the transfer of interpretation bias failed to happen. It is possible that participants did not imagine themselves in the suggested situations while reading the scenario but they were rather focused on finding the word meaning. Even if there are multiple training methods (i.e. auditory descriptions, verbal instructions), mental imagery boosts the improvements of interpretation bias in both positive and negative conditions (Menne-Lothmann et al., 2014). We consider that future studies should address this limitation.

As a conclusion, it is possible that CBM-I training effects would have been effective if scenarios would have been personally relevant, using ruminative specific words, and being presented in a multiple training sessions.

In relation to rumination, our conclusions cannot be firmly formulated. Due to the inefficacy of transferring interpretation biases we were unable to assess the effects of CBM-I training on daily rumination. However, results showed that there were no interaction between time and using daily rumination and neither between time and group interaction. We tested for pre to post changes in trait measures of rumination and social anxiety, but there were no

significant differences. However, we believe that using a clinical sample, the rumination – interpretation bias relation would be better reflected.

A major limitation of this study is about the low number of participants. It is possible that null effects of the training to be due to the low statistical power. Another limitation, is about the non – clinical nature of sample studies. Researches on CBM-I training support its efficacy in samples with anxiety and mood disorders compared to healthy controls (Menne-Lothmann et al., 2014). Finally, the inability to control if participants have imagine the proposed scenarios is another important limitation. Probably, a mixt between training methods (a combination between imaginary instructions and auditory descriptions) will have better results.

Understanding mechanisms of rumination that can diminish the development and maintenance of psychopathology is clearly an important aim for clinical research. CBM-I training show promising results in changing ruminative thinking in some studies. Results of current study may encourage future work to optimize CBM-I training methods, in order to reduce ruminative thoughts and associated psychopathology.

CHAPTER IV. GENEREAL CONCLUSIONS AND IMPLICATIONS

This thesis aimed to bidirectional investigate relations between rumination and automatic cognitive processes in distress. Cognitive theories affirm that maladaptive cognitive styles represents a risk factor for developing psychopathology (Abela and Hankin, 2008). Empirical evidences underlie the important role of impaired cognitive factors in maladaptive cognitive styles. However, a promising perspective integrating cognitive vulnerability-stress models of depression and impaired cognitive factors, is based on response style theory (Nolen-Hoeksema, 1991). Being conceptualized as a response to depression, response style theory proposed that individual's response to dysphoric mood, would influence the intensity and duration of dysphoric symptoms (Nolen-Hoeksema, 1991). In this framework, a recurrent focus on "symptoms of distress and on the possible causes and consequences of these symptoms" was defined as rumination (Nolen-Hoeksema et al., 2008). Theoretical conceptualizations of rumination proposed that rumination might be associated with impairments of cognitive factors in aspects of executive functions (e.g., Davis & Nolen-Hoeksema, 2000). In this thesis we investigated rumination and cognitive correlates using several experimental designs. We oriented our efforts toward core EFs and two important cognitive factors which are supposed to influence ruminative disposition. Regarding EFs we focused on core EFs: *working memory*, *shifting* and *inhibition* (proposed by Miyake et al., 2000) and tried to clarify the strength of the relationship with rumination. In order to find the magnitude of the relationship we run a comprehensive literature review on EFs. Then, due to the low effect sizes between EFs and rumination obtained in meta-analysis, we choose to investigate other cognitive factors through which rumination could influence emotional problems. We further investigated the role of attentional bias both as a mediator between rumination and state anxiety, and also as a predictor of state rumination. In addition, we explored the relation between induced cognitive depletion on state rumination. Finally, we use a CBM procedure in order to test if changing interpretational bias would reduce rumination. Below several conceptual and theoretical advances of this project are mentioned.

4.1 Theoretical and conceptual advances

The first chapter of the thesis framed rumination from and emotion regulation point of view. The most relevant theoretical accounts of rumination were the presented, and distinctions between various forms of rumination were made. The distinctiveness of rumination in comparison with similar processes and dysfunctional cognitive factors was also addressed. Finally, we also discussed relations with emotional and cognitive dysfunctions and relations with emotional disorders. The main objective of this thesis was to investigate the nature of the relationship between core EFs and cognitive biases and ruminative disposition in order to understand their role as mechanisms through which rumination can impact on emotional problems. This objective was that translated into a series of studies that aimed to increase our understanding of rumination and its correlates.

In our first study, the meta-analysis, we investigated the strength of the relation between core EFs and rumination. Our goal was to clarify some of the inconsistencies in the literature regarding the relations between rumination and EFs overall. We found no significant relation between rumination and EFs overall. We found that cognitive inhibition and shifting are associated with rumination (small effect size), but the assumption that people who ruminate cannot update their working memory content with adaptive thoughts was not supported. Although theoretical models hypothesize a relation between rumination and working memory, our results do not confirm this link. The only significant moderators were type of sample and

sample size, which moderated the rumination – inhibition relation. These findings suggest that rumination may be associated with some of the EFs but the magnitude of this association is relatively small.

Given that our meta-analysis indicated that core EFs are poorly or not at all associated with rumination, we decided to investigate other cognitive factors (i.e., attentional biases, interpretational biases) through which rumination could impact emotional problems. Based on cognitive theories highlighting the importance of cognitive biases as vulnerability factors to emotional distress (Mathews & MacLeod, 2005), we tested if ruminative disposition and attentional bias to negative information impacts on levels of state anxiety experienced by students prior to a mid-term exam. Our results indicated that the association between ruminative disposition and state anxiety experienced prior to a stressor is mediated by impaired attentional disengagement from negative information. We also showed that ruminative disposition predicts state anxiety over and above trait anxiety, and independently of reflection. The results of this study also indicate that ruminative disposition is characterized by impaired attentional disengagement from negative information. Moreover, the fact that state-anxiety was predicted by impaired attentional disengagement from, rather than facilitated attentional engagement with negative material suggests that the former pattern of attentional selectivity may play an important role in emotional responding to situational stress.

The third study was aimed to extend findings from Study 2; thus, we explored the relationships between attentional engagement and disengagement bias to sad and anxious stimuli and state rumination and subjective distress (that is frequently related with state rumination). Concerning the sad stimuli, we found that only attentional engagement bias was related to a general measure of state rumination. Regarding the anxious stimuli, we found that only disengagement bias scores were negatively associated with negative state rumination and positively associated with positive state rumination. Therefore, in the case of state rumination, we showed that links between rumination and attentional biases are evident for anxious material. However, in the case of sad material, the extent to which attention was selectively held by the negative stimuli compared to positive stimuli was positively related to subjective distress (which was contrary to our expectations) while for anxious material, it was negatively related.

In addition, in Study 3 we also explored the relationships between state rumination and cognitive depletion (assessed both subjectively – subjective fatigue – and physiologically – decreases in blood glucose levels). We found no significant differences on blood glucose levels and subjective fatigue in group for which depletion is induced through a difficult arithmetic task when compared to the group for which depletion has not been induced. However, it seems that the impact of cognitive depletion is influenced by the subjective fatigue. Our analysis suggested that the decrease in blood glucose was higher in participants who reported a high level of subjective fatigue only in the experimental group. Therefore concerning the impact of cognitive depletion on state rumination, we found no significant influence of cognitive depletion on negative and general state rumination, but we found that cognitive depletion influences positive rumination. These results are somehow contradictory to theoretical evidences and we suggest to be cautiously interpreted due to the poor internal consistency of positive state rumination measure. However, future investigations are needed in order to explore these aspects.

Our last study assessed the effect of a cognitive bias modification procedure on state rumination. Based on a diary approach, it was measured how much people engage in ruminative thinking about daily negative events. Using a novel interpretation bias modification procedure, we tried to change the way participants' interpreted ambiguous situations in order to reduce state rumination. Results showed that the training was ineffective; negatively trained

participants scoring higher positive (targets) interpretations in ambiguous situations than those positively trained. Subsequently, the training procedure did not influence daily rumination. Even though this study did not confirm our hypotheses, it could offer new insights for future research aiming to investigate different ways to reduce rumination. Furthermore, clinical implications of reducing rumination should motivate us to explore new procedures.

To summarize, these three studies examined mechanisms through which rumination could influence emotional problems and tested the effects of a training procedure on reducing state rumination. Our findings advance the filed by showing that attentional bias to negative information is related with both state and trait rumination and that complex and adapted to personal relevance trainings are needed in order to reduce rumination.

4.2 Methodological innovations

Besides theoretical and conceptual advances, the present thesis addresses several gaps in the literature on maladaptive emotion regulation strategies. First, a meta-analytical approach was used to draw firm conclusions on the relation between rumination and core EFs: *working memory*, *shifting* and *inhibition.* The use of a cross-sectional design allowing to measure variability of mood symptoms outside the laboratory, when approaching a real-world stressor (Study 2) is an important step for exploring the nature of rumination. Furthermore, due to the fact that the most of the literature is based on correlational designs, using the experimental designs (Studies 3 and 4) is an addition to the literature. Also, in these two studies we examined rumination as ecologically as possible relying on its real-life occurrence, an approach that does not only contribute to a better understanding of rumination itself, but also to its contribution to psychological problems.

The use of a computerized game to expose participants to negative feedback and to induce state rumination is another methodological improvement, which allowed us to address the human errors involved in giving negative feedback and to increase chances for a successful manipulation. Indeed, this strategy was quite effective in providing credible negative feedback, as suggested by the small number of participants who did not believe the feedback.

To our knowledge, CBM-I training in the field of rumination is relatively new (only two studies have used a similar procedure: Daches, Mor, & Hertel, 2015; Hertel et al., 2014). Even though the training procedure was not effective in our study, future research should build on these results and further develop the procedure. Improving the validity of ambiguous stimuli is one area that needs attention in future studies. The development and assessment of new computerized training procedures is important considering that they are relatively easy to disseminate and might help at-risk individuals (Baert, De Raedt, Schacht, & Koster, 2010).

4.3 General conclusions

The main conclusions of this PhD project are the following:

1. The overall effect size of the association between EFs and rumination, revealed no significant relation between the two. Also, no relation was found between rumination and working memory. However, we found small effect sizes for the association between rumination and shifting and between rumination and inhibition. These findings suggest that rumination may be associated with some EFs but the magnitude of this association is relatively small.
2. Ruminative disposition predicts both attentional biases to negative information (exam-related material, in our case) and state anxiety before a stressful event (mid-term exam, in our case). Ruminative disposition predicts state anxiety, over and above the level

predicted by trait anxiety. Ruminative disposition also predicts biased attentional disengagement from, but not biased attentional engagement with negative information. Biased attentional disengagement from negative information mediates the relation between ruminative disposition and state anxiety.

3. In the case of state rumination, attentional engagement bias with sad stimuli was associated with a measure of general rumination, but not with specific measures of negative and positive rumination. Attentional disengagement bias from anxious stimuli was negatively associated with negative state rumination, and positively associated with positive rumination.
4. Positive relations between attentional disengagement difficulties from sad material and subjective distress were found. However, a negative relation was observed between attentional disengagement from anxious material and subjective distress.
5. No significant influence of cognitive depletion on state rumination was observed, but this might be due to difficulties in actually inducing cognitive depletion base on the task we used.
6. Although CBM-I training has been described as an effective procedure of reducing maladaptive rumination, data from our study does not support this hypothesis. However, more studies, using methodologically improved training strategies, are needed to clarify this issue.

4.4 Limitations and future directions

As any research, the current thesis has several limitations. Limitations specific to each study are discussed in the dedicated section of the studies. The ones presented here are more general, and are relevant to all studies. Furthermore, these limitations should also be viewed as future research directions.

One important limitation is related to sample representativeness. Our samples consist mostly of undergraduates students, which constraints the generalization of our findings to other social groups. We suggest that future studies should include individuals from the general population. Another limitation is linked to the proportion of women in our studies, as the percentage of women was significantly higher that the percentage of men. Future studies should consider balancing for gender more carefully. Another limitation is the non-clinical nature of the samples. Numerous authors suggest that rumination is better expressed in individuals with emotional problems (e.g., dysphoric individuals; Nolen-Hoeksema et al., 2008). Despite the fact that our studies did not necessarily focus on psychopathological processes, we believe that investigating rumination in clinical samples could lead to helpful insights about its nature.

One of our four studies (Study 2) has a correlational design. Therefore, this study precludes conclusions regarding causality and directionality.

In spite of these limitations we believe this thesis brings valuable contributions to the literature regarding rumination (both trait and state) and its relations with cognitive functioning. By focusing not only on cognitive aspects, but also on emotions (e.g., anxiety), we hope that we have also provided some answers regarding the clinical relevance of rumination.

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