Rumination is posited to encompass both beneficial and deleterious roles in problem solving. Previous work has suggested these dual roles based upon categorical factors derived from reporting on measures of trait rumination. However, the effects of the continuous dimension of trait rumination on general problem solving performance have not yet been elucidated. In this study we examined the relationship between trait rumination and problem solving ability on Raven’s Advanced Progressive Matrices (RAPM). Results from two independent studies and a Monte Carlo simulation demonstrated a significant inverted U-shaped relationship between trait rumination and RAPM performance. These results suggest that the extent to which trait rumination is beneficial or deleterious to problem solving is contingent upon the degree of its expression.

Here, we approached the examination of trait rumination and problem solving ability with a more general perspective than previous research. We assessed the relationship between individual differences on standard measures of trait rumination and general problem solving ability. This approach allowed for a broad understanding of the relationship between these two factors. We hypothesized that, similar to the categorical distinctions of maladaptive vs. adaptive ruminative styles suggested in past research (e.g., Schoofs, Hermans, & Raes, 2010; Siegèl et al., 2004; Treynor, Gonzalez, & Nolen-Hoeksema, 2003; see Watkins, 2008), the continuum of trait rumination would reveal itself as both maladaptive and adaptive to general problem solving ability.

Increases in trait rumination expression and the presence of state rumination both produce biosignatures reflective of increased emotional arousal (see Siegèl & Thayer, 2008). For example, trait rumination is associated with amygdala activity when one is exposed to affective information (e.g., Ray et al., 2005) and state rumination is associated with increased cortisol production (Gianferante et al., 2014). Further, the modulating effects of trait rumination on sympathetic tone have been observed during complex cognitive performance. For instance,
Bermudez and Perez-Garcia (1996) measured sympathetic reactivity (i.e., systolic blood pressure) in high and low trait ruminators during both cognitively challenging (i.e., mental arithmetic) and simple reaction time tasks. These authors found that (1) high trait ruminators showed greater systolic blood pressure during the cognitively challenging task compared to the simple reaction time task, and (2) high trait ruminators showed elevated systolic blood pressure during the cognitively challenging task compared to the low trait ruminators. No significant differences were observed between groups on the simple reaction time task. Such results suggest that trait rumination is predictive of increase in emotional arousal during cognitive challenge.

Because of the association between trait rumination and emotional arousal, it is possible that trait rumination might show a similar association with cognitive performance as emotional arousal (see Easterbrook, 1959; Eysenck, 1976; Hebb, 1955). That is arousal is known to be beneficial for cognitive performance at moderate levels, whereas at higher levels, arousal leads to performance decline (see Easterbrook, 1959; Eysenck, 1976; Hebb, 1955). We hypothesized that if trait rumination reflects a tendency for emotional arousal during cognitive challenge, we would observe an inverted U-shaped relationship between trait rumination and problem solving performance (cf. Bargh & Cohen, 1978; Easterbrook, 1959; Eysenck, 1976; Hebb, 1955; Yerkes & Dodson, 1908). In other words, trait rumination would be adaptive and facilitate problem solving to a certain degree (i.e., the relationship's inflection point); thereafter, the expression of trait rumination would become maladaptive and detrimental to problem solving.

1. Study 1: trait rumination and problem solving

In Study 1, we assessed whether problem solving performance was predicted by individual differences in trait rumination. We hypothesized that we would observe an inverted U-shaped relationship between trait rumination and problem solving performance. This study was part of a larger series of studies in which unselected (i.e., not prescreened) undergraduate students were given several self-report measures regarding their mood and several general fluid ability tasks.

2. Methods

2.1. Participants and procedure

Ninety-six (n = 96) undergraduate students completed this study in its entirety. English fluency was assessed on a 4-point scale. Five participants were excluded from further analyses because of limited English fluency. Ninety-one (n = 91) reported that they were Excellent or Native English speakers. These participants comprised the final sample and were included in all subsequent analyses. Participants had a mean age of 24.87 years (SD = 7.01; range 18–57 years). Fifty-six percent (56.00%) of participants were female. Participants were compensated with course credit for their undergraduate psychology and neuroscience courses. All procedures were approved by the governing IRB. Data were collected by trained research assistants. Data collection was scheduled a priori for a one semester maximum.

2.2. Measures

Participants completed the Center for Epidemiological Studies Depression inventory (CESD; Radloff, 1977). This 20-item self-report asked participants to indicate on a 4-point Likert-type scale how often (Almost Never = 1, Sometimes = 2, Often = 3, Almost Always = 4) he or she utilized specific ruminative strategies when coping with negative mood. The scale measures the tendency to engage in rumination. A point was assigned to each item, weighted based on the response (i.e., Often = 3 points). Points for all 22-items were totaled for the CESD score. Raw scores are listed in Table 1. Raw scores are listed in sample characteristics; these scores were z-standardized in inferential analyses for ease of interpretation.

Participants completed a Ruminative Responses Scale (RRS; Treynor et al., 2003). This 22-item, self-report inventory required participants to indicate on a 4-point Likert-type scale how often (Almost Never = 1, Sometimes = 2, Often = 3, Almost Always = 4) he or she utilized specific ruminative strategies when coping with negative mood. The scale measures the tendency to engage in rumination. A point was assigned to each item, weighted based on the response (i.e., Often = 3 points). Points for all 22-items were totaled for the CESD score. Raw scores are listed in sample characteristics; these scores were z-standardized in inferential analyses for ease of interpretation.

3. Results and discussion

3.1. Sample characteristics

Participants had an average CESD score of 13.83 (SD = 9.61). Thirty-two (35.56%) participants met the criteria for dysphoria (M CESD = 24.25, SD = 7.70). Fifty-eight participants (63.74%) were classified as non-dysphoric (M CESD = 8.09, SD = 4.19). Participants answered an average of 53.14% problems correctly on the RAPM (SD = 19.92%). The study average CESD-Total score was 44.64 (SD = 13.17).

![Fig. 1. Example of RAPM problem.](image-url)
3.2. Inferential analyses

We used ordinary least squares linear and polynomial (quadratic) least squares regression modeling to assess whether several independent variables significantly predicted RAPM performance. CESD scores did not show linear or quadratic relationships with zRAPM performance (all model ps > .05). Further, dysphoric (M = -.023, SD = .97) and non-dysphoric (M = .14, SD = 1.04) participants did not perform significantly different on the zRAPM, t(89) = .72, p = .474.

We hypothesized an inverted U-shaped relationship between trait rumination and problem solving ability. We tested this hypothesis using quadratic least-squares (QLS) multiple regression. We assessed the extent to which zRRS-Total scores could predict zRAPM performance using QLS. This model showed that zRRS-Total significantly predicted zRAPM performance, F(2, 87) = 5.92, p = .004, R^2 = .12. The linear term of this model was not significant, \( \beta = .12, t(87) = 1.18, p = .242 \). The quadratic term was significant, \( \beta = -3.3, t(87) = -3.42, p = .001 \) (see Fig. 2A). Testing a linear hypothesis using ordinary least squares regression did not show a significant effect of zRRS-Total on zRAPM performance, F(1, 88) = 0.12, p = .730, R^2 < .001.

The QLS model showed that zRRS-Total had a facilitating effect on zRAPM performance until the curve’s inflection point, wherein increasing zRRS-Total became detrimental to zRAPM performance. Although individual variation from the QLS regression line was moderate, only 2.20% (n = 2) observations fell outside of the 95% confidence bands (see Fig. 2A). This suggests that the quadratic function was sufficient to confidently capture a majority of the observations. The QLS model was also shown to better account for the data compared to a linear model.

Results for Study 1 supported our hypothesis of an inverted U-shaped relationship between trait rumination and problem solving ability. However, it is important to note that the present effect was relatively small (i.e., 1 SD change in zRRS-Total resulted in ± 1/3 of an SD change in zRAPM; Cohen, 1988). Because this was the first time such results have been observed, we sought to test the robustness of the inverted U-shaped relationship between trait rumination and problem solving in a second study, utilizing the same procedure with a new group of subjects.

4. Study 2: robustness of inverted U-shaped relationship

In Study 2 we assessed whether the inverted U-shaped relationship was consistent across studies. We hypothesized that we would observe a similar inverted U-shaped result as was found in Study 1. Similar to Study 1, Study 2 was part of a larger series of studies in which unselect ed (i.e., not prescreened) undergraduate students completed self-report measures regarding their mood and several general fluid ability tasks.

5. Methods

5.1. Participants and procedure

Seventy-six (n = 76) undergraduate students who did not participate in Study 1, completed Study 2 in its entirety. Eight (n = 8)
participants were excluded from further analyses because of limited English fluency. Sixty-eight \((n = 68)\) reported that they were Excellent or Native English speakers. These participants were included in all subsequent analyses. Participants had a mean age of 22.45 years \((SD = 5.56; \text{range } 18–45 \text{ years})\). Approximately 59\% (58.82\%) of participants were female. Participants were compensated with course credit for their undergraduate psychology and neuroscience courses. All procedures were approved by the governing IRB. Data were collected by trained research assistants. Data collection was scheduled a priori for a one semester maximum.

6. Results

6.1. Sample characteristics

Participants had an average CESD score of 15.84 \((SD = 11.51)\). Twenty-seven \((39.70\%)\) participants met the criteria for dysphoria \((M_{CESD} = 27.74, SD = 7.89)\). Forty-one \((60.30\%)\) participants were classified as non-dysphoric \((M_{CESD} = 8.00, SD = 4.76)\). Participants answered an average of 58.17% correctly on the RAPM \((SD = 15.83\%)\). Average RRS-Total scores was 46.15 \((SD = 13.60)\).

6.2. Inferential analyses

CESD score did not show linear or quadratic relationships with zRAPM performance \((all \text{ model } p > .05)\). Further, dysphoric \((M = .09, SD = 1.10)\) and non-dysphoric \((M = .08, SD = .95)\) participants did not perform significantly different on the zRAPM, \(t(66) = .07, p = .946\). Consistent with Study 1, we assessed the extent to which zRRS-Total scores could predict zRAPM performance using QLS. This model showed zRRS-Total to significantly predict zRAPM performance, \(F(2, 65) = 3.52, p = .035, R^2 = .10\). The linear term of this model was not significant, \(\beta = .04, t(65) = .33, p = .745\). Also consistent with Study 1, the quadratic term was significant, \(\beta = -.27, t(65) = -2.61, p = .011\) \((\text{see Fig. 2B})\). Further, testing a solely linear hypothesis using ordinary least squares regression did not show a significant effect of zRRS-Total on zRAPM performance, \(F(1, 65) = .22, p = .638, R^2 < .01\).

6.3. Bootstrap analyses of Studies 1 and 2

The QLS model in Study 2 replicated the results from Study 1 by showing that zRRS-Total had an inverted U-shaped relationship with zRAPM performance. Also similar to Study 1, only two observations \((2.94\%)\) fell outside the 95\% confidence intervals. The present results illustrate that trait rumination shows a reliable inverted U-shaped relationship with problem solving ability.

7. General discussion

The present study assessed the extent to which the continuous dimension of trait rumination could predict general problem solving ability. Results from Study 1 confirmed our hypothesis by demonstrating a significant inverted U-shaped relationship between trait rumination and problem solving performance as measured by RAPM. Results from Study 2 also showed a significant inverted U-shaped relationship between trait rumination and RAPM performance. The Monte Carlo simulation demonstrated the robustness of the relationship between trait rumination and problem solving performance across data from Studies 1 and 2. The present results illustrate that trait rumination shows a reliable inverted U-shaped relationship with problem solving ability.

Self-regulation theories of rumination posit that it can have both beneficial and deleterious effects on problem solving. Categorical distinctions in ruminative style have shown both adaptive and maladaptive effects on cognition \((\text{e.g., Bernblum & Mor, 2010; Daches et al., 2010; Watkins & Moulds, 2005})\). Consistent with these categorical approaches, the present work has shown that the continuum of trait rumination also distinguishes itself as both adaptive and maladaptive for general problem solving, based upon the degree of trait expression. Increases in trait rumination are indicative of increases in physiological arousal \((\text{see Siegle & Thayer, 2008})\). Modulating effects of trait rumination on sympathetic nervous system activity are known to affect complex cognitive performance \((\text{e.g., Bermudez & Perez-Garcia, 1996})\). Therefore, it is possible that trait rumination, similar to emotional arousal, reflects a tendency to narrow the range of information to which one attends when confronted with cognitive challenge \((\text{see Whitmer & Gotlib, 2013})\). At moderate levels, this restriction of attentional range is known to be beneficial for cognitive performance. However, at higher levels, attentional range becomes overly restricted leading to performance decline \((\text{see Easterbrook, 1959; Eysenck, 1976; Hebb, 1955})\). During problem solving performance, limiting one’s range of attention to a restricted set of subgoals or solutions within the problem space \((\text{see Newell & Simon, 1972})\) can be beneficial to problem solving by limiting the overall amount of information that must be managed in working memory, increasing the probability of finding the correct solution \((\text{e.g., Carpenter et al., 1990})\). However, over-restriction of attention can lead to perseveration on particular subgoals, unsuccessful problem solutions, performance reappraisal, or on task unrelated thoughts \((\text{cf. Smallwood et al., 2014})\). Such over-restriction of attention would decrease the probability of finding a successful solution \((\text{cf. Koster, De Lissnyder, Derakshan, & De Raedt, 2011; Smallwood et al., 2014})\).

The present results are probably not due to rumination-related changes in executive function. Executive functioning plays a central role in problem solving. For example, tests of executive function have been shown to correlate highly with the RAPM task \((\text{Carpenter et al., 1990})\). Rumination has also been shown to relate to executive functioning \((\text{e.g., Bernblum & Mor, 2010; Philippot & Brutoux, 2008; Watkins & Brown, 2002})\). However, it is unlikely that executive function-related changes associated with trait rumination were influencing the present results. Such a hypothesis would predict a negative linear relationship between trait rumination and RAPM performance, where RAPM performance would monotonically decrease as trait rumination increased. Linear relationships between trait rumination and RAPM performance were not observed in the present studies.

Depressive symptoms and DI status were highly related to trait rumination in the present study,\(^1\) however, depression was not associated with RAPM performance. This suggests that the relationship between

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\(^1\) CESD and RRS-Total scores were associated at \(r = .76\) for Study 1 and \(r = .67\) for Study 2. Further, assessing DI status and RRS-Total revealed large effect sizes differences between these groups \(d = 2.09\) for Study 1 and \(d = 1.22\) for Study 2.