Implicit reappraisal as an emotional buffer: Reappraisal-related neural activity moderates the relationship between inattention and perceived stress during exposure to negative stimuli

Anoushka D. Shahane¹ · Richard B. Lopez¹ · Bryan T. Denny¹

Published online: 28 November 2018
© Psychonomic Society, Inc. 2018

Abstract

Emotion regulation often is an adaptive option in the face of elevated perceived stress. Perceived stress has been shown to have negative consequences for physical and mental health, including cognitive deficits and difficulties controlling attention. Cognitive reappraisal is an emotion regulation strategy that involves changing one's cognitive construal of an emotionally evocative stimulus to alter its emotional impact. Reappraisal can be implemented explicitly or implicitly (i.e., with or without conscious awareness). The objective of the present study was to examine whether *implicit* cognitive reappraisal during exposure to negative stimuli moderates the relationship between inattention and perceived stress. We found, as expected, that inattention problems are associated with increased perceived stress, but also found that one's spontaneous propensity to engage in cognitive reappraisal—as indexed by correspondence with a reliable thresholded whole-brain pattern of reappraisal implementation—moderated the relationship between inattention and perceived stress. Overall, the current study provides evidence that spontaneous reappraisal recruitment has a buffering effect on the relationship between inattention and perceived stress.

Keywords Emotion · Regulation · Implicit reappraisal · fMRI · Attention · Perceived stress

Introduction

Emotion regulation often is a useful, adaptive process that occurs by modulating one or more processes associated with emotion experience, including attention, appraisal, and behavioral responses (Gross, 1998a, 2015a; Ochsner & Gross, 2008). One particularly promising and well-studied emotion regulatory strategy is cognitive reappraisal, which involves changing one's cognitive construal of an emotionally evocative stimulus to alter its emotional impact on behavior, experience, and/or physiology

(Gross, 1998b, 2015a), including brain activity in regions associated with affective processing (e.g., amygdala; Buhle et al., 2013; Ochsner, Silvers, & Buhle, 2012; Denny & Ochsner, 2018).

While regulation often may be thought of as an explicit, conscious decision to change how one feels, emotion regulation may be engaged implicitly and habitually (Braunstein, Gross, & Ochsner, 2017; Gross, 2015a; Gyurak, Gross, & Etkin, 2011). Automatic or unintended emotion regulation can arise from implicit activation of higher-order, regulatory goals and does not require conscious awareness or attention to the emotion regulation process as it unfolds (Kooze & Rothermund, 2011; Mauss, Bunge, & Gross, 2007a; Wang et al., 2017). Implicit cognitive reappraisal involves changing one's appraisal of a negatively valenced stimulus without conscious awareness of this process (Wang et al., 2017). Furthermore, implicit emotion regulation research has suggested that an individual's stress response is directly related to their nonconscious processing and regulation of emotions (Gyurak et al., 2011). In addition, research shows that it can be as effective as explicit reappraisal, because it is less cognitively taxing. Also it is critical for well-being, because high demand for moment-to-moment

Anoushka D. Shahane and Richard B. Lopez contributed equally to this work.

Electronic supplementary material The online version of this article (<https://doi.org/10.3758/s13415-018-00676-x>) contains supplementary material, which is available to authorized users.

✉ Anoushka D. Shahane
anoushka.shahane@rice.edu

¹ Department of Psychological Sciences, Rice University, BioScience Research Collaborative Rm 761, 6500 Main St., MS-663, Houston, TX 77030, USA

regulation in everyday life is inefficient (Gyurak et al., 2011). In one study, nonconscious cognitive reappraisal resulted in decreases in emotion-related physiological activity during frustration (Yuan, Ding, Liu, & Yang, 2015). Neurobiological mechanisms underlying implicit reappraisal in the context of aversive stimuli include activation in the dorsomedial prefrontal cortex, the dorsolateral prefrontal cortex, and ventrolateral prefrontal cortex (Burklund, Creswell, Irwin, & Lieberman, 2014). In addition, another study (Drabant, McRae, Manuck, Hariri, & Gross, 2009) found that among individuals who report reappraisal as their preferred emotion regulatory strategy, prefrontal areas implicated in cognitive control, including reappraisal, are engaged more when simply viewing negatively-valenced faces—in the absence of any explicit goal to regulate.

Neuroimaging studies over the past decade have identified reliable, whole-brain correlates of explicit cognitive reappraisal of negative stimuli. For example, a meta-analysis of 48 neuroimaging reappraisal studies found that reappraisal consistently activated cognitive control regions and the lateral temporal cortex, but not the ventromedial prefrontal cortex, and modulated bilateral amygdalae. This meta-analysis suggests that reappraisal involves cognitive control to modify semantic representations of emotionally rich stimuli, which in turn weaken amygdala activity (Buhle et al., 2013). The present study examined the extent to which individuals *spontaneously* express this same reappraisal pattern representing *explicit, instructed* regulation, but in the context of an emotional processing task with threat-signaling stimuli during which emotions may be regulated *implicitly*. Specifically, we estimated correspondence between Buhle et al.'s (2013) meta-analytic reappraisal map and whole-brain patterns of activity during a task involving perceptual processing of negative facial expressions that has been used previously (Drabant et al., 2009; Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002). In doing so, we took a system-based approach, because some have recently argued that emotion regulatory capacities may be better captured by the coordination of whole-brain systems that support regulatory processes (e.g., the entire reappraisal implementation pattern), rather than discrete regions acting alone (Barrett & Satpute, 2013).

One risk factor or preceding condition where emotion regulation may be especially helpful is inattention/distractibility (i.e., people with more inattention problems are likely to attend to various stimuli in the environment that may be distressing, including social stimuli). Indeed, those with inattention problems are at higher risk of stress (Friedrichs, Igl, Larsson, & Larsson, 2012; Lackschewitz, Hüther, & Kröner-Herwig, 2008; Nigg et al., 2002; Nigg, 2006). Thus, more inattention signals a greater need to regulate. For example, individuals with attentional problems exhibit more difficulties

coping with stress than control participants (Wender, 1995). Inattention problems related to attention deficit hyperactivity disorder¹ (ADHD) are associated with comorbid anxiety, depression, and interpersonal relationship problems (Biederman, Newcorn, & Sprich, 1991; Friedrichs et al., 2012; Young, 2005); these comorbidities are also related to greater vulnerability to stress and poor coping skills (Bayram & Bilgel, 2008; Birk, Rogers, Shahane, & Urry, 2018; Connor-Smith & Compas, 2004). High propensity toward negative affect, which is associated with amygdala and cingulate cortex reactivity to threat or stress, is also seen as a marker for inattentive-related ADHD when in an elevated range (Nigg, 2006).

Adults with concentration difficulties, failure to give close attention, and ease of being distracted tend to show more vulnerability to daily life stressors (Lackschewitz et al., 2008). Perceived stress, the degree to which situations in one's life are appraised as stressful (Cohen, Kamarck, & Mermelstein, 1983), has been shown to impact negatively both physical health (Cohen, Tyrrell, & Smith, 1991; Nielsen, Kristensen, Schnohr, & Grønbaek, 2008; Stowell, Kiecolt-Glaser, & Glaser, 2001) and emotional well-being (Kraines, 1964; Racic et al., 2017; Watson, 1988). Individual differences in perceived stress are relevant in clinical as well as nonclinical domains. Even among healthy adults, perceived stress is associated with physical symptomology including headaches, back aches, and stomach acidity, as well as depressive symptomology (Cohen et al., 1983); further, stress is associated with increased risk for cardiovascular disease, respiratory diseases, as well as cancer mortality (Nielsen et al., 2008).

Depending on the context and individual, cognitive reappraisal has proven to be an adaptive emotion regulation strategy when one is faced with a distressing situation, such that those individuals with a higher propensity to engage in cognitive reappraisal are better at managing their stress than those with a relatively lower propensity (Gross, 1998a; Southwick, Litz, Charney, & Friedman, 2011). In an early study that demonstrated this effect, individuals reported diminished negative affect and distress when engaging in cognitive reappraisal during an emotionally disturbing video—compared with viewing the video naturally (Gross, 1998a). Several studies have since then confirmed that individuals who reappraise more often experience less negative affect in emotion-eliciting situations, thereby exhibiting positive effects in health over time (Dandoy & Goldstein, 1990; Gross & John, 2003; Mauss, Cook, Cheng, & Gross, 2007b). Consequently, implementing cognitive reappraisal strategies during highly stressful contexts may be protective against impaired

¹ A neurodevelopmental condition characterized by chronic inattention and/or hyperactivity-impulsivity affecting 1.2–7.3% adults worldwide (American Psychiatric Association, 2013; ADHD Institute, 2017). Symptoms of ADHD concentration difficulties, failure to give close attention, and ease of being distracted.

functioning (Troy, Wilhelm, Shallcross, & Mauss, 2010). One reason why the present study focuses on implicit cognitive reappraisal processes is because implicit processes have shown to be less costly to one's cognitive resources in reducing one's physiological response to a stressful situation relative to explicit reappraisal (Wang et al., 2017). Therefore, for individuals who suffer from inattention-related cognitive deficits, the ability to engage implicitly in cognitive reappraisal may be adaptive and a potential marker of an individual's emotional resilience.

Furthermore, although little work has specifically explored the relationship between cognitive reappraisal and inattention in nonclinical populations, several studies have looked at how attention influences emotional processes. Posner and Rothbart posit that attention allows one to perform cognitive and emotional computations and control levels of distress (Posner & Rothbart, 1998). Attention problems dictate subsequent affective experience (Wadlinger & Isaacowitz, 2011), and attentional load may alter responses to emotional stimuli (Viviani, 2013). Consequently, regions associated with attention and explicit emotion regulation overlap (Ochsner & Gross, 2008; Ochsner et al., 2012). Individuals with excessive inattention problems, such as those with ADHD, demonstrate emotion dysregulation, which has shown to arise from deficits in recognizing and allocating attention to emotional stimuli (Shaw, Stringaris, Nigg, & Leibenluft, 2014).

Attention deficits could be either a cause or consequence of poor implicit or explicit emotion regulation ability, as well as a cause or consequence of perceived stress. Individuals with high inattention may use maladaptive emotion regulation strategies in the context of stressful situations (Young, 2005). Alternatively, individuals who are highly distractible cannot focus their attention on the stimulus, which may be causing them emotional distress to begin with; thus, the ability to regulate is thwarted from the get-go. That said, those with high distractibility who *can* cognitively regulate, even implicitly, may fare better. As such, reappraisal, even when engaged in the brain implicitly, may play a key role in moderating the relationship between inattention/distractibility and stress. While a growing body of evidence is beginning to coalesce around the impact of cognitive control-related brain activity on cognitive processes affecting mental health (Yu-Feng et al., 2007), the question of whether brain patterns that correspond to explicit cognitive reappraisal during an *implicit* emotion regulation context moderate the relationship between inattention and perceived stress is less clear and therefore motivated the current study.

Specifically, we were interested in understanding the role of implicit cognitive reappraisal, as indexed by whole-brain²

patterns of activity that have been reliably associated with reappraisal implementation (Buhle et al., 2013), on the relationship between self-reported inattention problems and perceived stress in the context of appraising negative stimuli with no explicit instructions to regulate emotion. A similar approach has been leveraged in a recent study investigating how cognitive reappraisal ability (measured behaviorally) moderates the relationship between stress and depressive symptoms, such that at high levels of stress, women with high cognitive reappraisal ability exhibited less depressive symptoms than those with low cognitive reappraisal ability (Troy et al., 2010). Previous research investigating automatic emotion regulation has typically been exposure-based. Notably, recent research has identified shared neural mechanisms supporting explicit and implicit cognitive reappraisal. Specifically, overlapping regions of the PFC are recruited to reduce amygdala activation in both explicit and implicit regulation contexts (Burklund et al., 2014; Payer, Baicy, Lieberman, & London, 2012; Wang et al., 2017). Despite experiential differences, these findings suggest that intentional and incidental forms of emotion regulation may converge on a common neurocognitive pathway, bolstering the approach used in the present study. Convergence of explicit and implicit processes is common in other cognitive domains. For example, implicit and explicit learning and memory also are subject to similar encoding factors and rely on similar perceptual processes (Turk-Browne, Yi, & Chun, 2006).

In the present study, participants were instructed to either match a negatively-valenced (angry or fearful) target face with two other faces (presented at the bottom of the screen) or match a shape (Hariri et al., 2002). We surmise that the task in the present study engages implicit cognitive reappraisal, because it is similar to other implicit emotion regulation tasks with regard to eliciting negative appraisals (Cohen, Moyal, Lichtenstein-Vidne, & Henik, 2016; Strauss, Ossenfort, & Whearty, 2016; Wang et al., 2017). As such, in the present study, results reflecting greater correspondence between activity during the face matching task and the reappraisal meta-analytic map are consistent with greater implicit expression of cognitive reappraisal.

In addition, perceived stress was chosen as the primary outcome, as nonconscious processing and regulation of emotions is directly related to stress response (Gyurak et al., 2011), and because the exposure to negative stimuli (i.e., angry or fearful faces) is stress-inducing (Thoern, Grueschow, Ehlert, Ruff, & Kleim, 2016). In the present study, as a manipulation check of negative affect engagement during the face matching task, we assessed correspondence between patterns of brain activity during the face matching task and a validated whole-brain signature of negative affect appraisal (i.e., the Picture Induced Negative Emotion Signature (PINES); Chang, Gianaros, Manuck, Krishnan, & Wager, 2015).

We hypothesized that inattention problems would be a risk factor for increased perceived stress, while one's spontaneous

² The whole-brain pattern maps utilized were thresholded ($Z = 2$) to reduce the influence of potentially noisy and spurious voxel data in the whole-brain pattern.

propensity to express patterns of cognitive reappraisal—as indexed by correspondence (i.e., the extent to which their brain activity during implicit emotion regulation engaged explicit reappraisal regions) with a reliable whole-brain² pattern of reappraisal—should moderate the relationship between inattention and perceived stress. Importantly, we hypothesize that this is because attention abilities, perceived stress, and automatic reappraisal all necessitate some degree of cognitive control (Compton, Hofheimer, & Kazinka, 2013; McEwen, 2007; Wu, Dufford, Mackie, Egan, & Fan, 2016), and thus, underlying neural activity may further characterize the relationship among these variables.

Method

Participants

The present study analyzed publicly available data from the Washington University – University of Minnesota Consortium Human Connectome Project (HCP) database (Van Essen et al., 2013). Participants were healthy young adults and from a range of races and ethnicities in the United States with no documented history of mental or physical illness. A total of 1,045 participants completed the emotion processing task (see below for more details). We employed two exclusion criteria: (1) to account for motion-related artefacts during the functional runs, we excluded any participant who exhibited excessive motion, defined as 2-mm translation and/or 2 degrees of rotation; and/or (2) we excluded any participants who performed the matching task with less than 90% accuracy. These two criteria eliminated 66 participants. Additionally, to remove dependencies in the data and ensure the assumption of independence was met for our statistical analyses, we only analyzed one person per family, causing elimination of 612 participants. Two additional participants were excluded due to missing data. The final sample consisted of 365 participants (190 females; $M_{\text{age}} = 28.6$ years, range = 22–36 years).

Measures

Participants completed the NIH Toolbox Cognition Battery for adults (Heaton et al., 2014). This included the Perceived Stress Scale (Cohen et al., 1983), which is a 10-item, self-report measure assessing the participants perceived stress and feelings over the course of the past month, rated on a 5-point scale from 1 (never) to 5 (very often). Example items include, “How often have you been able to control irritations in your life?” or “How often have you felt difficulties were piling up so high that you could not overcome them?”

Participants also completed the DSM-oriented scale from the Achenbach System of Empirically Based Assessment

(ASEBA; Achenbach, 2015), which is based on DSM-IV criteria of inattention symptoms within attention deficit/hyperactivity problems. These criteria include forgetfulness, inability to concentrate, inability to finish a task, inability to maintain organization, inability to keep track of details, poor work performance, and prone to losing items. Importantly, DSM-oriented scales are not meant to identify DSM disorders but rather indicate proneness for that individual to develop the disorder and/or symptoms of the disorder (Achenbach, Bernstein, & Dumenci, 2005).

Participants completed an emotion processing task in which they were presented with blocks of trials in which they were instructed to either match a target face with two other faces (presented at the bottom of the screen) or match a shape (Hariri et al., 2002). All of the faces were negatively valenced, depicting angry or fearful expressions, thereby presenting participants with negative, threat/distress-inducing stimuli that could implicitly activate emotion regulation processes, such as reappraisal. Importantly, this procedure did not consist of any explicit instructions or demand characteristics to direct participants to regulate their emotional states in response to stimuli. There were six trials in one block. Each block was preceded by a 3,000-ms task cue (“face” or “shape”). Each stimulus was presented for 2,000 ms with a 1,000-ms intertrial interval. Consequently, each block was 21 seconds inclusive of the cue. Each run contained three face blocks and three shape blocks and 8 seconds of fixation at the end of each run (Hariri et al., 2002).

Image collection and feature selection

All imaging data were collected and pre-processed as a part of the HCP. All scanning was performed using a customized Siemens 3T “Connectome Skyra” scanner, which had a 32-channel head coil and 100-mT/m gradient coil. Task fMRI data were procured and processed through the HCP pipelines to generate data aligned to the 32 k surface mesh (Glasser et al., 2013). Functional data were pre-processed through the Minimal Pre-processing Pipeline (MPP; Glasser et al., 2013), which consisted of gradient unwarping, motion correction, EPI field distortion correction, registration into MNI space, and intensity normalization. Task fMRI data were analyzed using the FMRIB Software Library (FSL) to generate subject-specific, whole-brain contrast maps reflecting relative activity when participants were matching faces compared to matching shapes with no emotional content or valence (i.e., horizontally or vertically oriented ovals).

Buhle et al.’ (2013) whole-brain reappraisal meta-analytic map was procured by contacting the meta-analysis authors and included the posterior dorsomedial prefrontal cortex, bilateral dorsolateral prefrontal cortex, ventrolateral prefrontal cortex, and posterior parietal lobe, as shown in Figure 1. To reduce the influence of potentially noisy and spurious voxel

Fig. 1 Schematic depiction of method used to compute Reappraisal Correspondence Scores (RCS) to index putative implicit emotion regulation. The cognitive reappraisal Z-map derived from Buhle et al.'s (2013) meta-analysis (A) was correlated with each HCP participant's (individual participants denoted with P) contrast map for matching faces (vs.

matching shapes) (B). This resulted in an RCS for each participant, with higher values indicating relatively greater (thresholded) whole-brain correspondence with the reappraisal map and lower values indicating less correspondence (C)

data in the whole-brain pattern map, we applied a lower bound threshold of $Z = 2^3$. Each voxel in the map had an associated z -value indexing its importance and consistency in activation across studies of cognitive reappraisal. We estimated each participant's correlation between their whole-brain pattern during the face-matching task (i.e., relative activity for matching faces versus matching shapes) and the cognitive reappraisal effect size map using AFNI's *3ddot* tool to assess the extent to which their brain activity during implicit emotion regulation engaged explicit reappraisal regions. Specifically, we used the "*3ddot-dcor*" function to compute the correlation coefficients for each participant. This resulted in one correlation coefficient per participant (i.e., Reappraisal Correspondence Score [RCS]) that was entered in subsequent subject-level regression analyses.

Finally, to test our moderation hypotheses, the effect of explicit reappraisal brain pattern expression on the relationship between inattention problems and perceived stress during implicit emotion regulation was examined using a general linear model in the *jamovi* software package (Jamovi Project, 2018). Perceived stress (calculated as a sum; Cohen et al., 1983) was entered as the outcome variable, and inattention score (also calculated as a sum; Achenbach et al., 2005),

each individual's correlation of reappraisal brain pattern expression (RCS), and the interaction of the two were entered as the independent variables. All continuous predictor variables were mean-centered in the general linear model. Age and gender were included as covariates of no interest.⁴ A bias-corrected and accelerated bootstrap procedure with 10,000 resamplings was used to compute confidence intervals of the interaction effect (Fox & Weisberg, 2011).

We tested additional exploratory models, including inattention as the dependent variable, and RCS and perceived stress as the independent variables, as well as RCS as the dependent variable, with perceived stress and inattention as the independent variables. We also tested mediation relationships among the three variables. Furthermore, we investigated whether a region-of-interest (ROI) approach would yield equivalent results as the RCS approach. The dorsolateral prefrontal cortex was the primary ROI investigated given its robust activation in the successful regulation of emotions, including when participants engage in cognitive reappraisal (Buhle et al., 2013; Hermann, Bieber, Keck, Vaitl, & Stark, 2014; Nelson et al., 2015; Ochsner & Gross, 2005; Ochsner, Silvers, & Buhle, 2012). Lastly, as a manipulation check, we investigated the extent to which patterns of brain activity consistent with

³ Exploratory analyses were conducted using the whole-brain pattern map with 1) no thresholding, 2) thresholding at $Z = 2$, and 3) thresholding at $Z = 3.7$, as per the original meta-analysis by Buhle et al., 2013.

⁴ Effects of interest do not change if age and gender are included or excluded from the model.

negative affect appraisal, including the left and right amygdala and the Picture Induced Negative Emotion Signature (PINES; Chang, Gianaros, Manuck, Krishnan, & Wager, 2015), were engaged during Match Faces versus Match Shapes in the task in the present study. Please see [Supplemental Materials](#) for details on these manipulation checks. In these supplemental analyses, we also substituted the RCS in the general linear model with the recruitment of the left amygdala, right amygdala, and PINES pattern expression, respectively.

Results

First, as a manipulation check, we found that overall, participants showed significantly more expression of the whole-brain reappraisal signature when matching negative faces versus shapes, $t(364) = 9.84$, $p < 0.001$, $d = 0.52$. RCS scores were approximately normally distributed⁵ ($M = 0.15$, $SD = 0.29$, range = -0.65 to 0.69). Furthermore, participants overall showed significantly more expression of the PINES when matching negative faces versus shapes, $t(364) = 63.04$, $p < 0.001$, $d = 3.30$. Please see [Supplemental Materials](#) for additional manipulation checks.

We next tested a general linear model including perceived stress as the dependent variable; inattention score, each individual's RCS, and the interaction of the two were included as the independent variables, with all independent variables were centered. Age and gender were included as covariates in the model. Multicollinearity between the independent variables was low, because there was no correlation between reappraisal brain recruitment and inattention ($p = 0.53$). Importantly, there were no outliers, which were quantitatively defined as more than three interquartile ranges from the hinges (Howell, 2012).

Overall, the model we specified explained 14.3% of the variance in perceived stress scores ($R^2 = 0.14$, $F(5, 359) = 11.97$, $p < 0.001$). While RCS was analyzed continuously in the general linear model, for visualization and post-hoc analysis purposes, reappraisal recruitment was defined as low RCS (i.e., at least 1 standard deviation below the mean; $N = 66$), average RCS (i.e., between 1 standard deviation below the mean and 1 standard deviation above the mean; $N = 230$), and high RCS (i.e., at least one standard deviation above the mean; $N = 69$). Overall, there was a significant positive relationship between inattention problems and perceived stress, $t(364) = 7.05$, $b = 1.48$, $p < 0.001$ (Table 1; Figure 2).⁶ In addition, while there was no main effect of RCS on perceived stress, the interaction between reappraisal expression and inattention was significant, $t(364) = 2.19$, $b = -1.58$, $p = 0.029$ (95% bootstrapped CI with 10,000 iterations: -3.05 , -0.06).

⁵ We also ran a model with transformed RCS scores (using Fisher's r -to- z transformation). There were negligible differences in the model using the raw RCS scores versus the transformed values.

Table 1 Parameter estimates from multiple regression model predicting perceived stress scores

Predictor	Estimate	<i>t</i>	<i>p</i>
RCS	0.30	0.18	.86
Inattention	1.48	7.05	<0.001**
Gender [†]	−1.52	3.11	0.002*
Age	0.06	0.47	0.64
RCS*Inattention	−1.58	2.19	0.029*
$R^2 = 0.143$			

*Significant at the .05 level; **Significant at the .001 level. [†] Overall, females ($M = 50.5$, $SE = 0.67$) had more perceived stress than males ($M = 47.3$, $SE = 0.70$)

To unpack the interaction effect, we first examined the impact of RCS in predicting perceived stress at various levels of inattention. At low levels of inattention (i.e., at least one standard deviation below the mean for inattention), there were no significant differences in perceived stress among the three reappraisal expression groups (i.e., low, average, and high RCS). To estimate the value of inattention scores at which significant differences in RCS emerged, we implemented the Johnson–Neyman Technique (Johnson & Neyman, 1936). This revealed that differences in perceived stress among different reappraisal pattern recruiters (low, average, and high) emerged for individuals with high inattention scores ≥ 6.55 (total range⁷ = -3.32 , 7.68).

To further unpack the interaction, we ran simple slope analyses, which revealed that the slope of the regression line for individuals with low RCS was significantly greater than zero (i.e., with greater inattention being significantly associated with greater perceived stress), $t(65) = 6.29$, $b = 1.94$, $p < 0.001$. The slope of the regression line for individuals with average and high RCS was also significant in the same direction (i.e., $t(229) = 7.05$, $b = 1.48$, $p < 0.001$, for average RCS; and $t(68) = 3.58$, $b = 1.02$, $p < 0.001$, for high RCS). Importantly, however, there was a significant difference in the slopes of the regression lines for low and high RCS participants, $t(131) = 2.19$, $p = 0.030$. Consequently, the rate of change of perceived stress with inattention problems is higher for low implicit reappraisers than high implicit reappraisers

⁶ When the whole-brain map was unthresholded, the model we specified explained 14.5% of the variance in perceived stress scores ($R^2 = 0.15$, $F(5, 359) = 12.19$, $p < 0.001$). The interaction between reappraisal pattern expression and inattention was significant, $t(364) = 2.39$, $b = -2.63$, $p = 0.017$. When the whole-brain map was thresholded at $Z = 3.7$ (Buhle et al., 2013), the model we specified explained 14.0% of the variance in perceived stress scores ($R^2 = 0.14$, $F(5, 359) = 11.71$, $p < 0.001$). The interaction between reappraisal pattern expression and inattention was marginally significant $t(364) = 1.91$, $b = -1.15$, $p = 0.057$. The threshold of $Z = 2$ was chosen to decrease noise associated with the unthresholded meta-analytic map and include additional, variably-weighted voxels relative to the $Z = 3.7$ map, which may carry meaningful information about the distributed nature of reappraisal-related processes across disparate, noncontiguous voxels in the brain.

⁷ Inattention scores were centered.

Fig. 2 Effect of the predictor, inattention score (indexed by the DSM [ASEBA] oriented scale) on the dependent variable, perceived stress (indexed by the NIH Toolbox), at different levels of the moderator, reappraisal brain recruitment. SD, standard deviation

(Figure 2) (i.e., with evidence of a greater buffering effect for greater implicit reappraisal recruitment). There were no significant differences between the slopes of the average implicit reappraisers and high implicit reappraisers, nor between those of the average implicit reappraisers and low implicit reappraisers.

The exploratory analyses revealed no effect when inattention was the dependent variable, and RCS and perceived stress were the independent variables. Similarly, there was no effect when RCS was entered into the model as the dependent variable, with perceived stress and inattention as the independent variables. Mediated relationships among the three variables also did not reveal any significant indirect effects.

We explored whether a ROI analysis of the dorsolateral prefrontal cortex (DLPFC) would yield results consistent with the RCS approach. We independently defined a ROI in the right DLPFC using a 6-mm spherical mask centered on peak MNI coordinates $X = 42$, $Y = 21$, $Z = 45$ from the Buhle et al. (2013) meta-analysis. The model that we specified (with perceived stress as the dependent variable, inattention scores and DLPFC ROI values per participant as the independent variables, and controlling for age and gender (as per the original analyses)) explained 13.2% of the variance in perceived stress scores. The interaction between DLPFC activity and inattention was not significant $b = 0.38$, 95% CI $[-1.32, 2.08]$, $p = 0.66$.

Discussion

First, participants, on average, showed significant recruitment of the RCS when matching negative face stimuli (vs. matching shapes), which may be indicative of a greater need for implicit emotion regulation. The present study found that the effect of

inattention on perceived stress varied at different levels of participants' spontaneous engagement of the neural mechanisms supporting cognitive reappraisal; specifically, individuals with greater brain activity associated with reappraisal are able to attenuate the association between inattention and perceived stress when engaging in a simple perceptual negative emotion processing task. To test our hypotheses, we assessed the extent to which spontaneous expression of brain regions associated with cognitive reappraisal moderated the relationship between inattention and perceived stress during appraisal of negative stimuli without explicit instructions to regulate emotion.

Unsurprisingly, there was a strong positive relationship between inattention and perceived stress. This finding builds upon prior work; for example, individuals with attentional problems exhibit more problems coping with stress than individuals without attentional problems (Wender, 1995), and in Swedish twins, attention deficits were positively associated with increased risk of stressful life events (Friedrichs et al., 2012). In addition, the perceived stress measure used in the present study has been shown to reliably predict and/or reflect stress in normative populations (Kupst et al., 2015).

We conducted simple slope analyses, which revealed that individuals who have low reappraisal expression tended, on average, to report higher levels of perceived stress with inattention problems, while individuals with high reappraisal expression had lower increases in perceived stress with inattention problems, indicating a buffering effect of reappraisal on the inattention and perceived stress relationship. The slope of the high reappraisal recruiters was significantly different from that of the low reappraisal recruiters. Thus, the present study suggests that during implicit emotion regulation, individuals with greater engagement of brain regions associated with implementing reappraisal are able to attenuate or reduce

(i.e., buffer) the link between perceived stress and inattention. Furthermore, the analysis comparing the RCS approach to the standard ROI approach of the DLPFC suggests that taking a thresholded, whole-brain, distributed processing approach may be more reflective of spontaneous reappraisal patterns in an implicit emotion regulation context. After probing the interaction further to identify the inattention score threshold at which reappraisal differences emerge, we found that implicit reappraisal matters most for individuals with higher attention deficits.

It is important to note that we are inferring that expression of the (explicit) reappraisal network (Buhle et al., 2013) is indicative of some level of implicit emotion regulation processing, consistent with prior work on overlapping mechanisms between implicit and explicit emotion regulation (Burklund et al., 2014; Payer et al., 2012; Wang et al., 2017), although this inference should be interpreted cautiously. A majority of the literature relates greater PFC activation during emotion regulation to greater emotion regulation efficacy (Goldin, McRae, Ramel, & Gross, 2008; Kim & Hamann, 2007; Ochsner et al., 2012; Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008), even when the goal to regulate is implicit and people are not instructed to do so (Braunstein et al., 2017). Proceeding with this assumption, reappraisal brain region expression may “pump the breaks” on the relationship between attention deficits and perceived stress in the present study. Indeed, in the eating domain, the extent to which dieters spontaneously recruited ventrolateral PFC during exposure to appetizing food cues was associated with better self-regulatory outcomes (Lopez, Milyavskaya, Hofmann, & Heatherton, 2016).

The present study provides insight into dependencies between reappraisal, poor coping, and stress, as well as cognitive and behavioral issues like attention deficits. Whereas previous research has elucidated linkages among inattention and stress, explicit reappraisal region recruitment and stress (Troy, 2015), as well as explicit reappraisal region recruitment and attention (Ochsner & Gross, 2008; Ochsner et al., 2012), this study provides preliminary evidence that reappraisal expression influences perceived stress and inattention, even when measured unobtrusively and in the absence of any explicit instruction to regulate. While explicit and implicit reappraisal are experientially distinct, prior research has shown they share similar neurobiological mechanisms (Burklund et al., 2014; Payer et al., 2012; Wang et al., 2017). However, future work should investigate if a specific whole-brain pattern map of implicit (vs. explicit) cognitive reappraisal also yields similar results. Furthermore, it is important to note that our approach relies on a voxel-wise functional correspondence across individual brains. Although the HCP minimal preprocessing is well-validated and provides state-of-the-art anatomical normalization, future work may explore how functional normalization methods (e.g., hyperalignment) may improve functional

correspondence across individuals (Guntupalli et al., 2018; Haxby et al., 2011).

Overall, it is important to note that the present findings are correlational in nature. Hence, causality cannot be established by the current data. In particular, it is unclear if reappraisal-related regions are engaged because of implicit cognitive reappraisal or because of overlapping mechanisms involved in perceived stress and attention. In addition, a potential limitation of the study is that we, along with most researchers studying implicit processes, can only *infer* that the face and shape matching task was a context in which implicit cognitive reappraisal processes could have been called upon and engaged. Future experimental work may examine these relationships further by providing training to participants in explicit emotion regulation and then measuring subsequent implicit regulatory patterns and their effects on perceived stress as a function of individual differences in attention. Consistent with the hypothesis of a causal role for spontaneous reappraisal in reducing stress, longitudinal explicit training in reappraisal (particularly psychological distancing) has been shown to become more implicitly implementable over time and lead to longitudinal reductions in perceived stress (Denny & Ochsner, 2014).

Furthermore, the present work may have implications in translational and clinical domains. As alluded to above, markers of cognitive reappraisal are also markers of mental health and thus may potentially be used as a target for future therapies. Given how the present research substantiates potentially overlapping neural correlates of explicit reappraisal and implicit regulation, attention deficits, and perceived stress, future work may causally relate reappraisal activity to inattention and perceived stress directly. Indeed, cognitive reappraisal has potential to be used in therapeutic settings. For example, clinical trials for depression and ADHD indicate that practicing cognitive reappraisal is an adaptive, flexible strategy that should be implemented into clinical practice (Troy et al., 2010; Young, 2005). Reappraisal may represent a possible target for mental health interventions designed to foster adaptive emotion regulation. That said, as with any emotion regulation strategy, it is important to investigate for whom and under which circumstances reappraisal may be counterproductive (Doré, Silvers, & Ochsner, 2016) and how to flexibly select *when* to implement distancing and/or other emotion regulation strategies (Gross, 2015b), which represents an important skill of its own and an important avenue of future study.

In summary, the findings of this study revealed relationships among implicit emotion regulation, inattention, and perceived stress. Future work may continue to probe whether spontaneous reappraisal, as measured by functional brain imaging, may represent a clinically relevant biomarker of emotional health outcomes.

Acknowledgements This work was supported by a Rice University Faculty Initiatives Fund Grant. Data were provided by the Human

Connectome Project, WU-Minn Consortium (Principal Investigators: David Van Essen and Kamil Ugurbil; 1U54MH091657) funded by the 16 NIH Institutes and Centers that support the NIH Blueprint for Neuroscience Research; and by the McDonnell Center for Systems Neuroscience at Washington University. We also would like to thank Samuel Nastase for providing very helpful feedback on the analysis approach during the revision process.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

- Achenbach, T. M., Bernstein, A., & Dumenci, L. (2005). DSM-Oriented Scales and Statistically Based Syndromes for Ages 18 to 59: Linking Taxonomic Paradigms to Facilitate Multitaxonomic Approaches. *Journal of Personality Assessment*, 84(1), 49–63. https://doi.org/10.1207/s15327752jpa8401_10
- Achenbach, T. M. (2015). Achenbach System of Empirically Based Assessment (ASEBA). In *The Encyclopedia of Clinical Psychology* (pp. 1–8). American Cancer Society. <https://doi.org/10.1002/9781118625392.wbecp150>
- American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition. Arlington, American Psychiatric Association, 2013.
- Barrett, L. F., & Satpute, A. B. (2013). Large-scale brain networks in affective and social neuroscience: towards an integrative functional architecture of the brain. *Current Opinion in Neurobiology*, 23(3), 361–372. <https://doi.org/10.1016/j.conb.2012.12.012>
- Bayram, N., & Bilgel, N. (2008). The prevalence and socio-demographic correlations of depression, anxiety and stress among a group of university students. *Social Psychiatry and Psychiatric Epidemiology*, 43(8), 667–672. <https://doi.org/10.1007/s00127-008-0345-x>
- Biederman, J., Newcorn, J., & Sprich, S. (1991). Comorbidity of attention deficit hyperactivity disorder with conduct, depressive, anxiety, and other disorders. *The American Journal of Psychiatry*, 148(5), 564–577. <https://doi.org/10.1176/ajp.148.5.564>
- Birk, J. L., Rogers, A. H., Shahane, A. D., & Urry, H. L. (2018). The heart of control: Proactive cognitive control training limits anxious cardiac arousal under stress. *Motivation and Emotion*, 42(1), 64–78. <https://doi.org/10.1007/s11031-017-9659-x>
- Braunstein, L. M., Gross, J. J., & Ochsner, K. N. (2017). Explicit and implicit emotion regulation: a multi-level framework. *Social Cognitive and Affective Neuroscience*, 12(10), 1545–1557. <https://doi.org/10.1093/scan/nsx096>
- Buhle, J. T., Silvers, J. A., Wager, T. D., Lopez, R., Onyemekwu, C., Kober, H., ... Ochsner, K. N. (2013). Cognitive reappraisal of emotion: a meta-analysis of human neuroimaging studies. *Cerebral Cortex (New York, N.Y.: 1991)*, 24(11), 2981–2990. <https://doi.org/10.1093/cercor/bht154>
- Burklund, L. J., Creswell, J. D., Irwin, M. R., & Lieberman, M. D. (2014). The common and distinct neural bases of affect labeling and reappraisal in healthy adults. *Frontiers in Psychology*, 5, 221. <https://doi.org/10.3389/fpsyg.2014.00221>
- Chang, L. J., Gianaros, P. J., Manuck, S. B., Krishnan, A., & Wager, T. D. (2015). A Sensitive and Specific Neural Signature for Picture-Induced Negative Affect. *PLOS Biology*, 13(6), e1002180. <https://doi.org/10.1371/journal.pbio.1002180>
- Cohen, N., Moyal, N., Lichtenstein-Vidne, L., & Henik, A. (2016). Explicit vs. implicit emotional processing: The interaction between processing type and executive control. *Cognition and Emotion*, 30(2), 325–339. <https://doi.org/10.1080/02699931.2014.1000830>
- Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, 24(4), 385–396.
- Cohen, S., Tyrrell, D. A. J., & Smith, A. P. (1991). Psychological Stress and Susceptibility to the Common Cold. *New England Journal of Medicine*, 325(9), 606–612. <https://doi.org/10.1056/NEJM199108293250903>
- Compton, R. J., Hofheimer, J., & Kazinka, R. (2013). Stress regulation and cognitive control: evidence relating cortisol reactivity and neural responses to errors. *Cognitive, Affective & Behavioral Neuroscience*, 13(1), 152–163. <https://doi.org/10.3758/s13415-012-0126-6>
- Connor-Smith, J. K., & Compas, B. E. (2004). Coping as a Moderator of Relations Between Reactivity to Interpersonal Stress, Health Status, and Internalizing Problems. *Cognitive Therapy and Research*, 28(3), 347–368. <https://doi.org/10.1023/B:COTR.0000031806.25021.d5>
- Dandoy, A. C., & Goldstein, A. G. (1990). The use of cognitive appraisal to reduce stress reactions: A replication. *Journal of Social Behavior & Personality*, 5, 275–285.
- Denny, B. T., & Ochsner, K. N. (2018). Minding the emotional thermostat: Integrating social cognitive and affective neuroscience evidence to form a model of the cognitive control of emotion. In C. Schmah, K. L. Phan, & R. O. Friedel (Eds.), *Neurobiology of Personality Disorders* (pp. 95–109). New York: Oxford University Press.
- Denny, B. T., Ochsner, K. N., Weber, J., & Wager, T. D. (2014). Anticipatory brain activity predicts the success or failure of subsequent emotion regulation. *Social Cognitive and Affective Neuroscience*, 9(4), 403–411. <https://doi.org/10.1093/scan/nss148>
- Doré, B. P., Silvers, J. A., & Ochsner, K. N. (2016). Toward a Personalized Science of Emotion Regulation. *Social and Personality Psychology Compass*, 10(4), 171–187. <https://doi.org/10.1111/spc3.12240>
- Drabant, E. M., McRae, K., Manuck, S. B., Hariri, A. R., & Gross, J. J. (2009). Individual differences in typical reappraisal use predict amygdala and prefrontal responses. *Biological Psychiatry*, 65(5), 367–373. <https://doi.org/10.1016/j.biopsych.2008.09.007>
- Fox, J., & Weisberg, S. (2011). *An R Companion to Applied Regression* (2nd). Thousand Oaks: Sage Publications, Inc.
- Friedrichs, B., Igl, W., Larsson, H., & Larsson, J.-O. (2012). Coexisting Psychiatric Problems and Stressful Life Events in Adults With Symptoms of ADHD—A Large Swedish Population-Based Study of Twins. *Journal of Attention Disorders*, 16(1), 13–22. <https://doi.org/10.1177/1087054710376909>
- Glasser, M. F., Sotiropoulos, S. N., Wilson, J. A., Coalson, T. S., Fischl, B., Andersson, J. L., ... Jenkinson, M. (2013). The minimal preprocessing pipelines for the Human Connectome Project. *NeuroImage*, 80, 105–124. <https://doi.org/10.1016/j.neuroimage.2013.04.127>
- Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The Neural Bases of Emotion Regulation: Reappraisal and Suppression of Negative Emotion. *Biological Psychiatry*, 63(6), 577–586. <https://doi.org/10.1016/j.biopsych.2007.05.031>
- Gross, J. (1998a). Antecedent- and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology*, 74(1), 224–237.
- Gross, J. (1998b). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, 2(3), 271–299. <https://doi.org/10.1037/1089-2680.2.3.271>
- Gross, J. (2015a). *Emotion Regulation: Current Status and Future Prospects* (Vol. 26). <https://doi.org/10.1080/1047840X.2014.940781>
- Gross, J. (2015b). The Extended Process Model of Emotion Regulation: Elaborations, Applications, and Future Directions. *Psychological Inquiry*, 26(1), 130–137.
- Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-

- being. *Journal of Personality and Social Psychology*, 85(2), 348–362.
- Guntupalli, J. S., Feilong, M., & Haxby, J. V. (2018). A computational model of shared fine-scale structure in the human connectome. *PLOS Computational Biology*, 14(4), e1006120.
- Gyurak, A., Gross, J. J., & Etkin, A. (2011). Explicit and Implicit Emotion Regulation: A Dual-Process Framework. *Cognition & Emotion*, 25(3), 400–412. <https://doi.org/10.1080/02699931.2010.544160>
- Hariri, A. R., Tessitore, A., Mattay, V. S., Fera, F., & Weinberger, D. R. (2002). The amygdala response to emotional stimuli: a comparison of faces and scenes. *NeuroImage*, 17(1), 317–323.
- Haxby, J. V., Guntupalli, J. S., Connolly, A. C., Halchenko, Y. O., Conroy, B. R., Gobbini, M. I., ... Ramadge, P. J. (2011). A common, high-dimensional model of the representational space in human ventral temporal cortex. *Neuron*, 72(2), 404–416. <https://doi.org/10.1016/j.neuron.2011.08.026>
- Heaton, R. K., Akshoomoff, N., Tulsky, D., Mungas, D., Weintraub, S., Dikmen, S., ... Gershon, R. (2014). Reliability and validity of composite scores from the NIH Toolbox Cognition Battery in adults. *Journal of the International Neuropsychological Society: JINS*, 20(6), 588–598. <https://doi.org/10.1017/S1355617714000241>
- Hermann, A., Bieber, A., Keck, T., Vaitl, D., & Stark, R. (2014). Brain structural basis of cognitive reappraisal and expressive suppression. *Social Cognitive and Affective Neuroscience*, 9(9), 1435–1442. <https://doi.org/10.1093/scan/nst130>
- Howell, D. C. (2012). *Statistical Methods for Psychology*, 8th ed. Belmont, CA: Cengage Learning/Wadsworth Publishing. ISBN 978-1111835484
- Jamovi project (2018). Jamovi (Version 0.8) [Computer Software]. Retrieved from <https://www.jamovi.org> from February 2018 to November 2018.
- Johnson, P., & Neyman, J. (1936). Tests of Certain Linear Hypotheses and Their Application to Some Educational Problems. *Statistical Research Memoirs*, 1, 57–93.
- Kim, S. H., & Hamann, S. (2007). Neural correlates of positive and negative emotion regulation. *Journal of Cognitive Neuroscience*, 19(5), 776–798. <https://doi.org/10.1162/jocn.2007.19.5.776>
- Koole, S. L., & Rothermund, K. (2011). “I feel better but I don’t know why”: the psychology of implicit emotion regulation. *Cognition & Emotion*, 25(3), 389–399. <https://doi.org/10.1080/02699931.2010.550505>
- Kraimes, S. H. (1964). Life Stress and Mental Health: The Midtown Manhattan Study. *JAMA*, 187(6), 464–464. <https://doi.org/10.1001/jama.1964.03060190080033>
- Kupst, M. J., Butt, Z., Stoney, C. M., Griffith, J. W., Salsman, J. M., Folkman, S., & Cella, D. (2015). Assessing Stress and Self-Efficacy for the NIH Toolbox for Neurological and Behavioral Function. *Anxiety, Stress, and Coping*, 28(5), 531–544. <https://doi.org/10.1080/10615806.2014.994204>
- Lackschewitz, H., Hüther, G., & Kröner-Herwig, B. (2008). Physiological and psychological stress responses in adults with attention-deficit/hyperactivity disorder (ADHD). *Psychoneuroendocrinology*, 33(5), 612–624. <https://doi.org/10.1016/j.psyneuen.2008.01.016>
- Lopez, R. B., Milyavskaya, M., Hofmann, W., & Heatherton, T. F. (2016). Motivational and neural correlates of self-control of eating: A combined neuroimaging and experience sampling study in dieting female college students. *Appetite*, 103, 192–199. <https://doi.org/10.1016/j.appet.2016.03.027>
- Mauss, I., Bunge, S., & Gross, J. (2007a). Automatic Emotion Regulation. *Social and Personality Psychology Compass*, 1, 146–167. <https://doi.org/10.1111/j.1751-9004.2007.00005.x>
- Mauss, I. B., Cook, C. L., Cheng, J. Y. J., & Gross, J. J. (2007b). Individual differences in cognitive reappraisal: experiential and physiological responses to an anger provocation. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, 66(2), 116–124. <https://doi.org/10.1016/j.ijpsycho.2007.03.017>
- McEwen, B. S. (2007). Physiology and neurobiology of stress and adaptation: central role of the brain. *Physiological Reviews*, 87(3), 873–904. <https://doi.org/10.1152/physrev.00041.2006>
- Nelson, B. D., Fitzgerald, D. A., Klumpp, H., Shankman, S. A., & Phan, K. L. (2015). Prefrontal Engagement by Cognitive Reappraisal of Negative Faces. *Behavioural Brain Research*, 0, 218–225. <https://doi.org/10.1016/j.bbr.2014.11.034>
- Nielsen, N. R., Kristensen, T. S., Schnohr, P., & Grønbaek, M. (2008). Perceived Stress and Cause-specific Mortality among Men and Women: Results from a Prospective Cohort Study. *American Journal of Epidemiology*, 168(5), 481–491. <https://doi.org/10.1093/aje/kwn157>
- Nigg, J. T. (2006). *What Causes ADHD?: Understanding What Goes Wrong and Why*. Guilford Press.
- Nigg, J. T., John, O. P., Blaskey, L. G., Huang-Pollock, C. L., Willcutt, E. G., Hinshaw, S. P., & Pennington, B. (2002). Big five dimensions and ADHD symptoms: links between personality traits and clinical symptoms. *Journal of Personality and Social Psychology*, 83(2), 451–469. <https://doi.org/10.1037/0022-3514.83.2.451>
- Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences*, 9(5), 242–249. <https://doi.org/10.1016/j.tics.2005.03.010>
- Ochsner, K. N., & Gross, J. J. (2008). Cognitive Emotion Regulation: Insights from Social Cognitive and Affective Neuroscience. *Current Directions in Psychological Science*, 17(2), 153–158. <https://doi.org/10.1111/j.1467-8721.2008.00566.x>
- Ochsner, K. N., Silvers, J. A., & Buhle, J. T. (2012). Functional imaging studies of emotion regulation: a synthetic review and evolving model of the cognitive control of emotion. *Annals of the New York Academy of Sciences*, 1251, E1–24. <https://doi.org/10.1111/j.1749-6632.2012.06751.x>
- Payer, D. E., Baicy, K., Lieberman, M. D., & London, E. D. (2012). Overlapping neural substrates between intentional and incidental down-regulation of negative emotions. *Emotion (Washington, D.C.)*, 12(2), 229–235. <https://doi.org/10.1037/a0027421>
- Posner, M. I., & Rothbart, M. K. (1998). Attention, self-regulation and consciousness. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 353(1377), 1915–1927.
- Racic, M., Todorovic, R., Ivkovic, N., Masic, S., Joksimovic, B., & Kulic, M. (2017). Self-Perceived Stress in Relation to Anxiety, Depression and Health-related Quality of Life among Health Professions Students: A Cross-sectional Study from Bosnia and Herzegovina. *Slovenian Journal of Public Health*, 56(4), 251–259. <https://doi.org/10.1515/sjph-2017-0034>
- Shaw, P., Stringaris, A., Nigg, J., & Leibenluft, E. (2014). Emotional dysregulation and Attention-Deficit/Hyperactivity Disorder. *The American Journal of Psychiatry*, 171(3), 276–293. <https://doi.org/10.1176/appi.ajp.2013.13070966>
- Shire, Inc. ADHD Institute: Burden of ADHD and Epidemiology, 2017.
- Southwick, S. M., Litz, B. T., Charney, D., & Friedman, M. J. (2011). *Resilience and Mental Health: Challenges Across the Lifespan*. Cambridge University Press.
- Stowell, J. R., Kiecolt-Glaser, J. K., & Glaser, R. (2001). Perceived Stress and Cellular Immunity: When Coping Counts. *Journal of Behavioral Medicine*, 24(4), 323–339. <https://doi.org/10.1023/A:1010630801589>
- Strauss, G. P., Ossenfort, K. L., & Whearty, K. M. (2016). Reappraisal and Distraction Emotion Regulation Strategies Are Associated with Distinct Patterns of Visual Attention and Differing Levels of Cognitive Demand. *PLoS ONE*, 11(11). <https://doi.org/10.1371/journal.pone.0162290>
- Thoern, H. A., Grueschow, M., Ehlert, U., Ruff, C. C., & Kleim, B. (2016). Attentional Bias towards Positive Emotion Predicts Stress

- Resilience. *PLOS ONE*, 11(3), e0148368. <https://doi.org/10.1371/journal.pone.0148368>
- Troy, A. S. (2015). Reappraisal and resilience to stress: Context must be considered. *The Behavioral and Brain Sciences*, 38, e123. <https://doi.org/10.1017/S0140525X1400171X>
- Troy, A. S., Wilhelm, F. H., Shallcross, A. J., & Mauss, I. B. (2010). Seeing the Silver Lining: Cognitive Reappraisal Ability Moderates the Relationship Between Stress and Depressive Symptoms. *Emotion (Washington, D.C.)*, 10(6), 783–795. <https://doi.org/10.1037/a0020262>
- Turk-Browne, N. B., Yi, D.-J., & Chun, M. M. (2006). Linking Implicit and Explicit Memory: Common Encoding Factors and Shared Representations. *Neuron*, 49(6), 917–927. <https://doi.org/10.1016/j.neuron.2006.01.030>
- Van Essen, D. C., Smith, S. M., Barch, D. M., Behrens, T. E. J., Yacoub, E., & Ugurbil, K. (2013). The WU-Minn Human Connectome Project: An overview. *NeuroImage*, 80, 62–79. <https://doi.org/10.1016/j.neuroimage.2013.05.041>
- Viviani, R. (2013). Emotion regulation, attention to emotion, and the ventral attentional network. *Frontiers in Human Neuroscience*, 7. <https://doi.org/10.3389/fnhum.2013.00746>
- Wadlinger, H. A., & Isaacowitz, D. M. (2011). Fixing our focus: Training attention to regulate emotion. *Personality and Social Psychology Review: An Official Journal of the Society for Personality and Social Psychology, Inc.*, 15(1), 75–102. <https://doi.org/10.1177/1088868310365565>
- Wager, T. D., Davidson, M. L., Hughes, B. L., Lindquist, M. A., & Ochsner, K. N. (2008). Prefrontal-subcortical pathways mediating successful emotion regulation. *Neuron*, 59(6), 1037–1050. <https://doi.org/10.1016/j.neuron.2008.09.006>
- Wang, H.-Y., Xu, G.-Q., Ni, M.-F., Zhang, C.-H., Sun, X.-P., Chang, Y., & Zhang, B.-W. (2017). Neural mechanisms of implicit cognitive reappraisal: Preceding descriptions alter emotional response to unpleasant images. *Neuroscience*, 347, 65–75. <https://doi.org/10.1016/j.neuroscience.2017.01.047>
- Watson, D. (1988). Intraindividual and interindividual analyses of positive and negative affect: their relation to health complaints, perceived stress, and daily activities. *Journal of Personality and Social Psychology*, 54(6), 1020–1030.
- Wender, P. H. (1995). Attention-deficit hyperactivity disorder in adults. New York: Oxford University Press.
- Wu, T., Dufford, A. J., Mackie, M.-A., Egan, L. J., & Fan, J. (2016). The Capacity of Cognitive Control Estimated from a Perceptual Decision Making Task. *Scientific Reports*, 6, 34025. <https://doi.org/10.1038/srep34025>
- Young, S. (2005). Coping strategies used by adults with ADHD. *Personality and Individual Differences*, 38(4), 809–816. <https://doi.org/10.1016/j.paid.2004.06.005>
- Yuan, J., Ding, N., Liu, Y., & Yang, J. (2015). Unconscious emotion regulation: Nonconscious reappraisal decreases emotion-related physiological reactivity during frustration. *Cognition & Emotion*, 29(6), 1042–1053. <https://doi.org/10.1080/02699931.2014.965663>
- Yu-Feng, Z., Yong, H., Chao-Zhe, Z., Qing-Jiu, C., Man-Qiu, S., Meng, L., ... Yu-Feng, W. (2007). Altered baseline brain activity in children with ADHD revealed by resting-state functional MRI. *Brain and Development*, 29(2), 83–91. <https://doi.org/10.1016/j.braindev.2006.07.002>