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## Angry Rumination and the Self-Regulation of Aggression

THOMAS F. DENSON

*University of New South Wales*

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**B**en has just had a morning meeting with his supervisor. During the meeting, the supervisor rudely and sarcastically informs Ben that he will not be receiving the big promotion he has been expecting. Although Ben is furious, he tries to control his anger, as he does not wish to jeopardize his job. Nonetheless, Ben cannot stop thinking about his supervisor's insulting comments and how much he would really like to tell him off. The more he dwells on it, the more upset he becomes. Finally, at the day's end, Ben sees his supervisor in the hallway. Ben *can no longer restrain his aggressive impulses* and loudly berates his supervisor.

This anecdote illustrates the difficulty we often encounter when attempting to manage our anger and refrain from aggressive behavior. Indeed, the proximal cause for many acts of aggression is the simple loss of self-control (DeWall, Baumeister,

Stillman, & Gailliot, 2007). Individuals and societies have long struggled with controlling anger and aggression. Anger and aggression are human universals, presumably selected for their survival and social communication value. Nonetheless, in modern society, displays of anger and aggression are often counterproductive and a source of distress for aggressive individuals and those around them. The many consequences of unrestrained anger are severe and include verbal attacks, physical and sexual assaults, road rage, and domestic violence. Despite the prevalence of anger and the substantial burdens it inflicts on families and society, there is an absence of scientifically rigorous, systematic research on the regulation of aggressive thoughts, feelings, and actions. Perhaps one reason that aggression is not under control is because the underlying mechanisms are poorly understood. In the present chapter, I review evidence on one such mechanism, angry rumination, which I propose depletes self-control mechanisms and thereby increases aggression.

## ANGRY RUMINATION

For most people, angry feelings and associated physiological arousal tend to dissipate within 10–15 minutes (Doob & Climie, 1972; Fridhandler & Averill, 1982; Tyson, 1998). This suggests that individuals are usually quite capable of effectively regulating anger. Nonetheless, there are times when we fail to control our anger. Indeed, despite the evidence that anger and arousal are short-lived, there are many instances in which acts of anger-induced aggression are perpetrated over much longer time periods (as was the case with Ben's situation in the opening anecdote). One cognitive-affective mechanism that can explain such instances is angry rumination. Factor analytic approaches reveal that angry rumination involves two components: (a) thinking about and reliving an angering event, as well as (b) mentally rehearsing acts of revenge (Denson, Pedersen, & Miller, 2006; Sukhodolsky, Golub, & Cromwell, 2001).

A handful of laboratory experiments confirm that angry rumination increases anger and aggression. In one experiment, participants were insulted by a fictitious participant and then asked to hit a punching bag. While hitting the punching bag, participants were induced to either ruminate by thinking of the insulting person or asked to engage in distraction by thinking about becoming physically fit (Bushman, 2002). Following the rumination manipulation, participants were then given the opportunity to deliver loud blasts of white noise to the fictitious provocateur. Relative to distraction, rumination increased aggression. Additional research suggests that preventing individuals from ruminating reduces aggression toward an insulting confederate (Konecni, 1974), and that relative to distraction, rumination augments anger (Rusting & Nolen-Hoeksema, 1998).

In a series of three studies, Bushman and colleagues showed that experimental manipulations of rumination consistently augmented aggression toward those who had nothing to do with the initial provocation (i.e., displaced aggression; Bushman, Bonacci, Pedersen, Vasquez, & Miller, 2005). These findings were robust across different operational definitions aggression (i.e., physical and written aggression measures), and both relatively short-term (25 minutes) and long-term intervals (8 hours). These findings provide a framework for understanding anecdotal evidence

of individuals who aggress against their romantic partner or children after a stressful day at work. Additional research has since replicated these effects (Denson et al., 2006, Experiment 2).

How might angry rumination augment aggression? As a potential explanation, researchers (Denson et al., 2006; Miller, Pedersen, Earleywine, & Pollock, 2003; Rusting & Nolen-Hoeksema, 1998) have relied on associative network theories of affect (e.g., Berkowitz, 1990, 1993; Bower, 1981; Clark & Isen, 1981; Forgas, 1992, 1993, 1999; Ingram, 1984; Lang, 1984; Teasdale, 1983). Such theories conceptualize emotions as central nodes linked to memories associated with a particular emotion. When a person experiences an emotion, activation spreads throughout the associated network, which in turn prolongs that emotional experience. In the context of anger, each time a person thinks about a provoking incident, new activation spreads through the network, which strengthens the associations. Rusting and Nolen-Hoeksema (1998) hypothesized that rumination maintains and augments anger as well as the cognitive accessibility of aggression-related constructs, thus creating a state of readiness to engage in subsequent aggressive behavior. According to associative network theories, this state of readiness translates into aggressive behavior by biasing the cognitive appraisal process in an aggressive manner (Anderson & Bushman, 2002).

## RESOURCE DEPLETION MODELS OF SELF-REGULATION

In addition to an associative network explanation of the aggression-augmenting effects of angry rumination, I suggest that a second, complimentary process in which self-control is diminished as a result of angry rumination might also be informative in this regard. Resource depletion models of self-regulation suggest that executive functioning is a limited yet renewable resource (e.g., Baumeister, Muraven, & Tice, 2000; DeWall et al., 2007). Thus, engaging in activities that rely on executive functioning abilities will temporarily deplete these resources. With these resources temporarily depleted, individuals are less able to control their behavior and emotions, and therefore at increased risk of disinhibited behavior. For instance, research demonstrates that temporary depletion of executive functioning resources impairs the ability to engage in appropriate social interaction (Vohs, Lasaleta, & Fennis, Chapter 17, this volume; von Hippel & Gonsalkorale, 2005; von Hippel & Ronay, Chapter 18, this volume). These models also help explain anecdotal accounts of overeating, drug relapse, and binge drinking being more common at the end of a long, cognitively taxing day than at the end of a restful day (e.g., Baumeister et al., 2000), and may even partially explain why an Australian government report found that 67% of homicides are committed between 6 p.m. and 6 a.m. (Mouzos, 2005).

Thus, resource depletion accounts of aggressive behavior suggest that loss of self-control is a *proximal* cause of aggression (e.g., DeWall et al., 2007). Experimental evidence confirms that aggression is more likely when executive functioning resources are depleted, even when the source of the depletion is unrelated to anger. For instance, DeWall et al. (2007) reported that across five studies, resource depletion manipulations, such as asking hungry participants not to eat a tempting doughnut, resulted in increased aggression when followed by an insult. Additional resource depletion manipulations that increased aggression included activities as

diverse as being asked not to pay attention to words that appeared at the bottom of the screen during a videotaped interview, the Stroop task, and asking participants to cross off the letter *e* followed by asking them not to when the letter *e* was in the presence of other vowels. These experiments provide strong evidence supporting the notion that nearly any task that requires some form of inhibition or self-control makes subsequent impulsive aggression more likely.

The loss of self-control as a proximal cause hypothesis is consistent with Bushman et al.'s (2005) findings that rumination increased displaced aggression. In those experiments, participants were first provoked by the experimenter, induced to ruminate or engage in a distraction task, and finally presented with the opportunity to aggress against a fictitious participant who had nothing to do with the initial provocation. For half of the participants, the target of displaced aggression provided innocuous feedback and was therefore completely innocent. However, for the other half of participants, the fictitious participant provided slightly annoying feedback on a written task by stating that the actual participant "could have done better" (Experiments 2 and 3), or behaved somewhat incompetently in their role as the research assistant (Experiment 1). Rumination only increased aggression in the presence of the second minor annoyance. Presumably, provoked participants induced to ruminate were able to appropriately regulate their anger and control their aggressive behavior toward the innocent participant, unless the participant was the source of a second, unexpected annoyance. In those instances, participants were presumably unable to inhibit their aggressive behavior. The predisposition to aggress that rumination creates was unleashed, resulting in excessive, impulsive aggression toward an undeserving other.

Might angry rumination overwhelm self-control resources in the same manner as refraining from eating a tempting doughnut? Given the numerous negative consequences associated with acts of anger-induced aggression, one can assume that under most circumstances, ruminating individuals are motivated to (a) down-regulate the subjective experience of anger, (b) suppress angry thoughts, and (c) restrain themselves from engaging in acts of aggression. Each of these can be conceptualized as emotion regulation, thought suppression, and acts of behavioral volition, respectively. All of these consume substantial self-regulatory resources. Indeed, regulating emotions, suppressing one's thoughts, and exerting control over one's behavior individually contribute to a subsequent loss of self-control (see, this volume, Baumeister & Alquist, Chapter 2; Tice, Chapter 12; Vohs et al., Chapter 17). Because angry rumination is likely comprised of all three resource-depleting processes, its effects on the failure to control aggression may be particularly harmful. Moreover, the degree of resources depleted is likely further exacerbated in the presence of certain situational factors such as an extremely strong provocation or situations that call for self-control, such as the presence of strong social norms against aggression.

## CLUES FROM ALCOHOL AND AGGRESSION RESEARCH

Experimental social psychological research on the effects of alcohol on aggression offers insight regarding how angry rumination might increase aggression via impaired self-regulatory resources. One of the most robust findings as confirmed

by multiple meta-analyses of laboratory experiments is that when provoked, alcohol increases aggression (Bushman & Cooper, 1990; Hull & Bond, 1986; Ito, Miller, & Pollock, 1996; Steele & Southwick, 1985). Furthermore, alcohol intoxication has been implicated in nearly all forms of violence including family violence, violence-related emergency room visits, sexual aggression, homicide, and suicide (e.g., Boles & Miotto, 2003; Hoaken & Stewart, 2003). Surveys reveal that perpetrators were under the influence of alcohol in up to 86% of homicides, 60% of sexual assaults, and 57% of marital violence cases (Roizen, 1993).

Alcohol is widely known to decrease self-control and acutely impair executive functioning (Giancola, 2000). Indeed, alcohol dependence is associated with prefrontal cortical atrophy (Harper & Kril, 1990), and even neurologically normal alcoholics show functional deficits in dorsolateral prefrontal cortex (DLPFC) functioning (Dao-Castellana et al., 1998). Steele and colleagues (Steele & Josephs, 1990; Steele & Southwick, 1985) have proposed that acute alcohol intoxication impairs one's ability to attend to inhibitory cues in the environment and increases attention toward highly salient cues such as provocation. They termed this phenomenon *alcohol myopia* (Steele & Josephs, 1990). Despite its theoretical importance, only two experiments have investigated alcohol myopia theory. In one experiment, my colleagues and I administered either alcohol or placebo to 74 participants, followed by an insult from the experimenter (Denson, Aviles, et al., 2008). They were then given a slightly annoying comment from a fictitious participant, which was written in red ink and therefore highly salient, or embedded in a paragraph of blue ink and therefore low in salience. Results showed that intoxicated participants who were exposed to the highly salient comment were significantly more aggressive than the other conditions (Figure 14.1). Thus, intoxicated participants were only

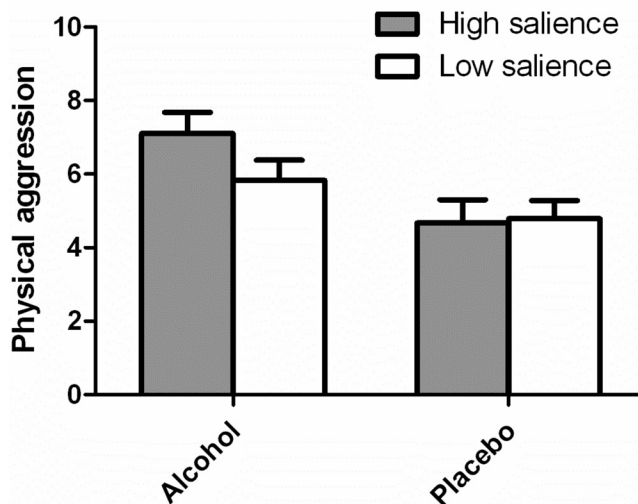


Figure 14.1 Physical aggression means and standard errors as a function of alcohol condition and the salience of a slightly annoying comment.

able to pay attention to highly salient cues, which suggests impairment in attention and disinhibition. As expected, there was no effect of the salience manipulation on nonimpaired, sober participants, because they were able to attend to both comments equally well.

If rumination temporarily depletes self-control resources, might it also create a “myopic” mental state similar to that produced by acute alcohol intoxication in which individuals are only able to pay attention to aggression-related affect, thoughts, behavior, and arousal? Recall that angry rumination consists of regulating one’s anger and planning revenge (Denson et al., 2006). In addition, angry rumination requires a conscious effort to control unwanted thoughts and aggressive behavior. Thought control, emotion regulation, behavioral self-control, and planning ability are integral elements of appropriate executive functioning.

Experimental evidence suggests that rumination does indeed create a myopic cognitive state focused on anger and aggression. Specifically, in a recent experiment in which participants were insulted by the experimenter and then induced to ruminate or engage in a distracting task, rumination augmented participants’ focus on aggressive cognition (Pedersen, Denson, Goss, Vasquez, & Miller, 2007). Rumination was manipulated by asking participants to write about their experiences in the experiment thus far. This included their thoughts, feelings, and describing who they interacted with. In the distraction condition, participants wrote about the layout of the university campus. The dependent measure was an implicit word completion task in which words could be completed aggressively or not (e.g., “h\_t” could be completed as “hit” or “hat”). Three types of words were included: aggressive action (e.g., kill), angry affect (e.g., annoyed), and arousal (e.g., tense). Results showed that participants induced to ruminate about the provocation reported increased aggressive action and anger words compared to participants who were distracted ( $ps < .05$ ; Figure 14.2). Two additional studies reported that ruminating increased the cognitive accessibility of anger and that this effect can persist up to 24 hours following a laboratory angry rumination manipulation (Kross, Ayduk, & Mischel, 2005; Wimalaweera & Moulds, 2008). Thus, it appears that angry rumination alters attentional resources such that it creates a myopic state similar to that produced by acute alcohol intoxication.

The temporary depletion of self-regulatory resources from alcohol intoxication decreases one’s ability to inhibit aggression and appropriately regulate anger and impulsive aggression. If alcohol and angry rumination impair self-regulatory resources and thereby increase aggression, we should expect to see a synergistic effect of alcohol and angry rumination on aggressive behavior. Survey research and experimental manipulations of acute alcohol intoxication and angry rumination support this notion. One cross-sectional survey of university students reported that heavy drinkers who ruminated frequently engaged in the most self-reported alcohol-induced aggression (Borders, Smucker Barnwell, & Earleywine, 2006). My own research has provided experimental support for a causal, synergistic effect of alcohol and rumination on aggression (Denson, Spanovic, et al., 2008). In this study, 97 volunteers from a university and surrounding community either consumed vodka mixed with Sprite or a placebo beverage. Breath alcohol levels

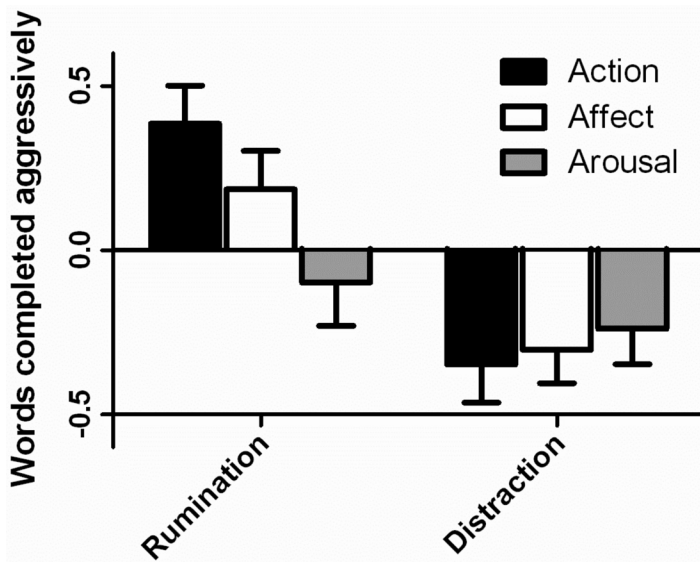


Figure 14.2 The cognitive accessibility of aggressive action, affect, and arousal words as a function of rumination and distraction following a provocation. Values are  $z$ -scores.

(BAL) reached a mean of .06, thus indicating a mild level of intoxication (i.e., the equivalent of two drinks for most people). All participants were subsequently insulted by the experimenter. Half of the participants were then instructed to ruminate about the provocation by completing a “writing task” in which they wrote about their experience in the experiment for 20 minutes. The other half was instructed to engage in a distracting task by writing about the layout of their university campus for 20 minutes. Participants were then given the opportunity to aggress against a fictitious participant by specifying how long this other person should submerge their hand in a bucket of painfully cold ice water. For half of the participants, the fictitious participant provided neutral feedback, whereas for the other half, the fictitious participant indicated that the actual participant “could have done better.” Participants who drank alcohol were induced to ruminate and when exposed to a slightly annoying fictitious participant they demonstrated significantly higher levels of aggression against the target than participants in all of the other conditions. This study provided the first evidence for a synergistic effect of rumination and alcohol intoxication on aggression. Thus, it appears that the combination of these two variables depleted the self-regulatory capacity of participants, which led to excessive levels of aggression. It is noteworthy that rumination only augmented alcohol-induced aggression when the second participant was slightly annoying. In the absence of this annoyance, participants refrained from excessive aggression. A second recent study found that distracting people from rumination reduced the aggression-augmenting effect of alcohol intoxication (Giancola & Corman, 2007).

## INDIVIDUAL DIFFERENCES

### *Self-Control, Executive Functioning, and Overcontrolled Hostility*

Individual differences provide further insight into the mechanisms underlying the control of aggressive behavior. Simply put, some individuals are more successful at controlling aggression than others. For instance, following a resource depletion task, DeWall et al. (2007) found that participants high in trait self-control were less likely to report aggressive intentions than those low in trait self-control. Because individuals high in trait self-control tend to inhibit inappropriate behavior across a variety of general situations (and not just aggression-inducing situations), this suggests that individuals high in self-control tend to have highly effective executive functioning abilities. As such, they should be capable of inhibiting unwanted rumination to some extent. There is also some experimental evidence that individuals with superior executive functioning are less aggressive than those with impaired executive functioning (e.g., Santor, Ingram, & Kusumakar, 2003).

Paradoxically, yet consistent with resource depletion accounts of aggression, for most people, the more we try to control aggressive behavior, the less successful we are. Indeed, controlling emotional responses is no simple task (Baumeister, Vohs, DeWall, & Zhang, 2007; Tice, Chapter 12, this volume). This phenomenon, in which individuals attempt to control aggressive behavior, yet eventually lose the ability to refrain from violence, is known as overcontrolled hostility (Megargee, Cook, & Mendelsohn, 1967). Overcontrolled hostility is a component of the Minnesota Multiphasic Personality Inventory and has been observed in prison populations (Verona & Carbonell, 2000). Violent offenders are often incapable of restraining aggressive behavior, despite quite substantial rewards for controlling aggression (e.g., early release, access to visitors). Presumably many violent offenders are highly motivated to control themselves once they are in prison. Nevertheless, resource depletion models would suggest that chronic attempts at self-control, such as restraining acts of violence among prisoners, might actually result in rebound effects in aggression. What might be the underlying psychological mechanisms responsible for these effects? It might be that those high in overcontrolled hostility tend to habitually ruminate following provocations.

### *Trait Displaced Aggression*

One type of aggressive personality that is characterized by angry rumination is trait displaced aggression. To date, most research on aggressive personality has focused on direct aggression (also called general aggression). These individuals tend to respond to provocations with anger and immediate retaliation. Clearly, such individuals are not capable of adaptively controlling their emotional and behavioral responses to provocations, and likely have deficits in executive control. By contrast, my research has focused on trait displaced aggression (Denson et al., 2006; Denson, Pedersen, Ronquillo, & Nandy, in press). Dispositional displaced aggression is a multifaceted construct. When provoked, individuals high on the dimension tend to (a) initially inhibit aggressive behavior, (b) yet continue to ruminate about the provocation over time, and (c) eventually take it out on the innocent.

When individuals high in displaced aggression are provoked, they tend to inhibit aggressive behavior. This suggests at least normal levels of executive control in contrast to those high in direct aggression. Furthermore, correlational evidence reveals that individual differences in displaced aggression are associated with behavioral inhibition, whereas direct aggression is associated with behavioral approach (Carver & White, 1994; Denson et al., 2006; Harmon-Jones & Sigelman, 2001). Experimental evidence provides further support for the notion that those high in displaced aggression are capable of inhibiting aggression immediately following a provocation. In a recent experiment, 50 University of New South Wales introductory psychology students were asked to complete an essay describing their life goals, which was to be ostensibly exchanged with another participant who would provide feedback (e.g., Moons & Mackie, 2007). In the provocation condition, participants were insulted by the fictitious participant (i.e., “The bottom line is that this person just sounds very young and naive. That’s it.”). In the control condition, participants read the same feedback (to control for exposure to negative information), but were told that it was written about another participant. As expected provoked participants reported experiencing greater negative affect than participants in the control condition,  $t(48) = 2.01, p < .05$ . When provoked, individual differences in general aggression predicted the loudness and duration of a blast of white noise that would be delivered to the fictitious participant,  $\beta = .39, p < .04$ , whereas individual differences in displaced aggression did not,  $\beta = .24, ns$  (Denson, 2008). No differences emerged for unprovoked participants. Thus, even when given the opportunity to harm the source of their anger, individuals high in trait displaced aggression inhibited this response.

This inhibition comes at a cost to the innocent. Those high in displaced aggression continue to ruminate about the provocation, which likely reduces their ability to control themselves once these self-control resources are depleted. For instance, in two laboratory experiments that manipulated provocation and rumination, individual differences in displaced aggression predicted aggression toward an undeserving fictitious participant, whereas individual differences in direct aggression did not (Denson et al., 2006). It is noteworthy that these experiments also manipulated whether the target of aggression was completely innocent or mildly annoying. This manipulation did not interact with trait displaced aggression, suggesting that these individuals simply aggressed against whoever was readily available, innocent or otherwise. In this sense, individuals high in trait displaced aggression evidenced “true” displaced aggression, whereas most individuals aggress only in the presence of a subsequent minor annoyance (i.e., triggered displaced aggression; Vasquez, Denson, Pedersen, Stenstrom, & Miller, 2005). Furthermore, individual differences in displaced aggression, but not direct aggression, predict self-reported road rage and domestic abuse (Denson et al., 2006).

In summary, converging evidence from social and personality research suggests that whether angry rumination is experimentally manipulated or assessed as an individual difference variable, aggression is a likely outcome, presumably due to depleted executive control. Those with high levels of executive functioning are generally able to exert control over their aggressive impulses, whereas those who tend to have difficulty regulating aggressive cognition, affect, and behavior experience rebound effects that exacerbate all three.

## A SOCIAL NEUROSCIENCE APPROACH TO ANGRY RUMINATION

Identification of the neural regions mediating angry rumination might provide insight into concrete, physiological processes whereby rumination depletes executive control resources. The prefrontal cortex (PFC) is involved in the regulation and control of negative emotions. It should therefore come as no surprise that several studies have documented prefrontal structural and functional differences in the brains of violent offenders relative to matched controls. For instance, one study compared structural differences between individuals with antisocial personality disorder to normal controls, substance-dependent individuals, and a group of individuals with other psychiatric disorders (Raine, Lencz, Bihrlé, LaCasse, & Colletti, 2000). Results showed that there was an 11% to 14% deficit in prefrontal gray matter among the antisocial group relative to the other groups. A functional neuroimaging study found reduced glucose metabolism in the PFC in a group of neurodergers relative to a matched control group (Raine, Buchsbaum, & LaCasse, 1997).

The lateral and medial regions of the PFC share rich connectivity with cortical and subcortical limbic structures. An integral part of the circuit that underlies self-control consists of the dorsolateral prefrontal cortex (DLPFC) and the dorsal anterior cingulate cortex (DACC; Cohen, Botvinick, & Carter, 2000; Kerns et al., 2004). The DACC is of particular interest because it has been implicated as mediating the subjective experience of social pain in response to ostracism as well as the emotional component of physical pain (Eisenberger & Lieberman, 2004; Eisenberger, Lieberman, & Williams, 2003). The DACC has also been linked to noticing discrepancies in the environment (i.e., cognitive conflict; Kerns et al., 2004).

Engaging in self-control or completing neuropsychological measures that rely on executive functioning abilities recruits prefrontal neural substrates. Thus, activities that deplete executive functioning should be observable in prefrontal neural activity. For example, in a recent neuroimaging study, white participants completed a white–black Implicit Association Test (IAT), subsequently exposed to black and white faces during imaging, and completed the Stroop color-naming task (Richeson et al., 2003). Results showed that IAT scores strongly correlated with increased activity in response to black faces in the DLPFC and DACC. Thus, prejudiced individuals recruited brain regions involved in executive control and negative affect to a greater extent than less prejudiced individuals. Furthermore, activity in the DLPFC and DACC predicted performance on the Stroop task and mediated the effect of IAT scores on Stroop performance.

A second study examined the resource-depleting effects of emotion regulation on neural activity (Inzlicht & Gutsell, 2007) as assessed by a component of the event-related potential known as the error-related negativity (ERN). The ERN originates in the DACC and thus reflects activity in that region (van Veen & Carter, 2002). In this study, participants saw excerpts from sadness-inducing films that depicted animals suffering and dying. Participants were asked to suppress their emotions (suppression condition) or simply watch the films (control condition). Following the film clip, participants completed a Stroop task, which is a measure of inhibitory ability. Results showed that participants asked to suppress

their emotional responses demonstrated worse performance on the Stroop and this effect was mediated by decreases in ERN signals.

There is also good reason to suspect that the medial prefrontal cortex (MPFC) might play a role in angry rumination. The MPFC is associated with emotion regulation and thus also at risk for rumination-induced depletion. Because angry rumination contains components of self-reflection, social cognition, negative affect, and emotion regulation by maintaining or increasing anger after a provocation, it should involve the recruitment of brain regions associated with these mental events such as the MPFC, lateral PFC, insula, and cingulate cortex (Amodio & Frith, 2006; Lévesque et al., 2003; Ochsner, Bunge, Gross, & Gabrieli, 2002; Phan, Wager, Taylor, & Liberzon, 2002). Consistent with this notion, Ray et al. (2005) reported that when participants were asked to decrease their negative affective responses to aversive photographs, a composite measure of trait rumination was correlated with ACC and MPFC activity. The MPFC is associated with the self-awareness of emotions and self-relevant cognition (Lane, Fink, Chau, & Dolan, 1997; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Ochsner et al., 2004). The MPFC is active when participants are asked to monitor their emotional state, reflect on their feelings, and when reappraising their responses to distressing visual stimuli (Amodio & Frith, 2006; Ochsner et al., 2002, 2004). Moreover, the MPFC also appears related to the personality trait of self-awareness (Eisenberger, Liberman, & Satpute, 2005). Because rumination involves thinking about and regulating one's affective state, the MPFC should be especially relevant to rumination.

Together these studies suggest that the regulation of affective, cognitive, and behavioral responses involves recruitment of the DACC, DLPFC, and MPFC. Might we also expect to see similar regions active during angry rumination? In a test of this hypothesis, 20 undergraduates completed measures of direct and displaced aggression (Denson et al., in press). Approximately 2 weeks later, participants returned for a neuroimaging study ostensibly investigating cognitive ability and memory. In the first phase of the experiment, participants were presented with difficult anagrams on a computer monitor for 15 seconds each and asked to state the answer aloud or respond with "no answer" if they did not know the answer. The experimenter then insulted participants by rudely telling them that they could not follow simple instructions. Relative to baseline activity, the provocation increased activity in the DACC, DLPFC, and MPFC. Thus, neural regions involved in executive control, negative affect, and emotion regulation showed increased activity in response to the provocation. Moreover, the DACC was strongly correlated with direct aggression and self-reported anger, thus identifying the neural substrate mediating the subjective experience of anger. Activity in the MPFC was correlated with individual differences in displaced aggression. These individual differences data suggest that immediately following a provocation, those high in direct aggression recruit a neural region associated with anger, whereas those high in displaced aggression rely on a neural region associated with emotion regulation and the self-awareness of negative emotions.

The next portion of the study involved counterbalanced within-participants experimental manipulations of rumination and distraction. Specifically, following the provocation, participants were asked to engage in a "memory task." Using a modified rumination task from my prior research (Denson et al., 2006), during

the rumination block, participants were asked to think about what had occurred in the experiment so far, who they interacted with, how they were feeling, and so on. During the distraction block, participants were asked to think about affectively neutral events (e.g., a double-decker bus going down the street, pigeons pecking at the ground) adapted from Rusting and Nolen-Hoeksema (1998). Relative to distraction, rumination increased activity in the DACC, DLPFC, and MPFC. Moreover, self-reported rumination was correlated with activity in the MPFC, thus identifying the neural substrate mediating the subjective experience of angry rumination. Individual differences in displaced aggression, but not direct aggression, were correlated with MPFC activity as well (Denson et al., in press).

In summary, these findings demonstrate that provocation and subsequent angry rumination recruit neural regions underlying executive control and emotion regulation. Depletion in these regions likely increases the risk of subsequent aggression.

## CONCLUSIONS AND FUTURE DIRECTIONS

The evidence reviewed here provides convergent evidence from multiple perspectives that angry rumination depletes executive control resources. These depleted resources are a risk factor for aggression. In addition to research examining angry rumination within the context of aggressive behavior, future research might explore the extent to which angry rumination impacts other behaviors such as binge eating and drinking. In other words, if angry rumination depletes executive functioning resources, then it will likely affect other behaviors that require subsequent self-control as well. Additional future research might explore mechanisms for improving self-control in response to provocations. For example, glucose consumption has been demonstrated to increase self-control in other domains (Gailliot et al., 2007). Perhaps glucose consumed following a provocation may increase one's ability to effectively reduce angry rumination and thereby better control aggressive behavior. Other approaches include self-control exercises that increase self-control capability over time (Baumeister & Alquist, Chapter 2, this volume). Eventually, such research may lead to successful, cost-effective, evidence-based interventions for reducing the aggression associated with angry rumination.

## AUTHOR NOTE

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