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Learning to keep your cool: Reducing aggression through the experimental modification of cognitive control

Benjamin M. Wilkowski, Sarah E. Crowe, and Elizabeth Louise Ferguson

Department of Psychology, University of Wyoming, Laramie, WY, USA

Prior research suggests that recruiting cognitive control resources following exposure to hostile stimuli may allow individuals to more effectively override their aggressive urges. In the current study, a cognitive modification procedure was developed to encourage participants to perform this cognitive operation. It successfully encouraged cognitive control recruitment following hostile primes. More importantly, this procedure allowed individuals prone to hostile attributions to override their aggressive urges. Interestingly, it also led to a slight increase in aggression at low levels of hostile attributions. Discussion focused on theoretical and practical implications of the hypothesised effect, as well as possible explanations for the non-hypothesised effect.

Keywords: Aggression; Anger; Cognitive control; Cognitive bias modification; Hostile attributions.

An essential part of normal socialisation involves learning to “keep your cool”. Although acts of retaliatory aggression are quite common in young children, they typically decrease with age (Tremblay et al., 1999). Social feedback slowly teaches individuals that acting on aggressive impulses is unacceptable and should be controlled (Nagin & Tremblay, 2001).

This has led some to suggest that anger regulation develops as many skills do, through simple practice (Meier, Robinson, & Wilkowski, 2006). After a lifetime of controlling one’s self in angering situations, anger regulation processes should become more habitual. In the current investigation, we sought to test a model of the cognitive processes involved in learning to control one’s aggressive impulses (Wilkowski & Robinson, 2008a). As explained in greater detail later, we predicted that recruiting cognitive control resources following exposure to hostile stimuli would improve one’s ability to control aggressive impulses. To test this prediction, a cognitive modification procedure (MacLeod & Mathews, 2012) was developed to encourage one group of participants to recruit cognitive control resources following hostile primes. We first expected that this procedure would increase cognitive control recruitment following hostile primes. More

Correspondence should be addressed to: Benjamin M. Wilkowski, Department of Psychology, University of Wyoming, Department 3415, 1000 E. University Ave., Laramie, WY 82071, USA. E-mail: BWilkows@uwyo.edu

importantly, we predicted that it would allow individuals to override their retaliatory impulses and act less aggressively.

ANGER REGULATION AND COGNITIVE CONTROL

Although anger and aggression can sometimes be functional (van Kleef & Cote, 2007), they are typically viewed as undesirable, leading to social rejection (Card & Little, 2006) and undermining social relationships (Baron et al., 2007). As a result, people are frequently motivated to control their aggressive impulses. As children grow older, their self-regulatory abilities improve (Jones, Rothbart, & Posner, 2003), and most children use these abilities to decrease their anger and aggression (Cole et al., 2011; Tremblay et al., 1999).

Yet how is cognitive control used to regulate aggressive impulses? Cognitive neuroscience research indicates that cognitive control is best conceptualised as a limited capacity resource situated in the prefrontal cortex (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Automatic processes are often sufficient to complete well-practiced tasks, so these resources often lie dormant. However, automatic processes sometimes lead to undesirable consequences. In such instances, cognitive control must be recruited and used to override the undesirable automatic process (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999).

Drawing upon this conceptualisation, Wilkowski and Robinson (2008a) argued that cognitive control recruitment is critically involved in the down-regulation of retaliatory impulses. Once provoked, an individual must recruit cognitive control resources in order to override revenge goals. Prior research supports these ideas. Wilkowski and Robinson (2008b) first provided evidence that low trait anger individuals recruit cognitive control resources following exposure to hostile stimuli. On each trial of their task (Figure 1), participants were first primed with a hostile or non-hostile word. They then completed one trial of a flanker task (Eriksen & Eriksen, 1974), in

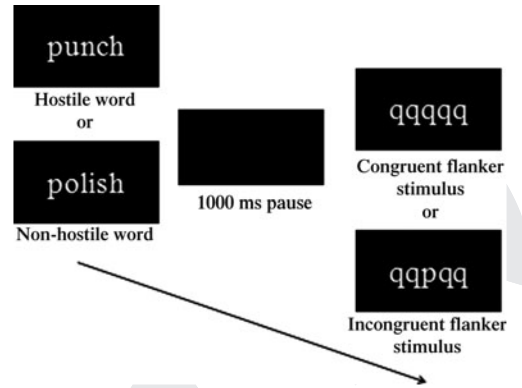

Figure 1. *Visual depiction of the primed flanker task.*

which they identified the central letter of a letter string. On congruent trials, all letters are identical (e.g., qqqqq), and the task is quite easy. On incongruent trials, however, the central letter is surrounded by several incongruent flanker letters (e.g., qqpqq). These trials require one to recruit cognitive control resources and use them to override the tendency to respond to the more predominant flanker letters (Coles, Gratton, Bashore, Eriksen, & Donchin, 1985; Eriksen & Hoffman, 1973). This is a time-consuming process, resulting in increased RTs for incongruent trials.

Wilkowski and Robinson (2008b) found that low trait anger individuals became more capable of overriding their automatic responses following hostile primes, as evidenced by a reduced flanker interference effect under such circumstances. In a subsequent investigation, Wilkowski, Robinson, and Troop-Gordon (2010) provided evidence that cognitive control recruitment specifically allows individuals to override retaliatory desires. In these studies, individuals who recruited cognitive control resources following hostile primes were more capable of inhibiting the desire for revenge and forgiving their provocateurs.

LEARNING WHEN TO RECRUIT COGNITIVE CONTROL

Yet how does an individual learn to recruit cognitive control resources in hostile situations?

Wilkowski and Robinson (2008a) suggested that this is the simple result of practice (cf. Denson, Capper, Oaten, Friese, & Schofield, 2011). If an individual routinely practices controlling their anger in hostile situations, the hostile situation itself will trigger cognitive control recruitment.

The first purpose of this investigation was to experimentally model this learning process in the laboratory. A great deal of clinical research indicates that brief learning experiences can temporarily alter participants' information-processing styles (MacLeod & Mathews, 2012). For example, asking them to repeatedly locate a stimulus appearing opposite from a threat can train participants to disengage attention from threatening stimuli. Impressively, such procedures effectively reduce participants' anxious reaction to stress.

Research from the cognitive control literature converges upon similar conclusions. Several studies indicate that people can learn to recruit cognitive control resources in response to informative cues. In the original demonstration of this, Gratton, Coles, and Donchin (1992, Study 3) had participants complete a flanker task in which cues reliably indicated the likelihood of an incongruent stimulus. Before each trial, cues appeared indicated that there was an 80%, 50% or 20% likelihood of an incongruent trial. When there was an 80% chance of incongruency, participants significantly reduced the flanker interference effect. As such, participants can learn to recruit cognitive control resources when cues indicate they are needed (cf. Ghinescu, Schachtman, Stadler, Fabiani, & Gratton, 2010).

Building upon this, we developed a cognitive modification procedure designed to encourage participants to recruit cognitive control following hostile stimuli. On each trial of the task, participants first categorised a hostile or non-hostile prime before responding to one flanker stimulus (modelled after Wilkowski & Robinson, 2008b). Participants randomly assigned to the cognitive modification condition were explicitly told that hostile primes indicated a high probability of an incongruent flanker stimulus immediately thereafter (modelled after Gratton et al., 1992). In effect, these instructions encouraged participants to recruit cognitive control resources following hostile primes. We compared this to a non-modification condition in which incongruent and congruent stimuli were equally likely following hostile primes (modelled after Gratton et al.' s control condition).

We predicted that the cognitive modification procedure would reduce the magnitude of the flanker interference effect following hostile primes. In effect, it would teach participants to recruit cognitive control in such situations. More importantly, though, we expected that this procedure would help participants override their aggressive impulses.

ISOLATING THE ROLE OF COGNITIVE CONTROL RECRUITMENT IN AGGRESSION

According to Wilkowski and Robinson's (2008a) model, cognitive control recruitment allows individuals to more effectively override retaliatory impulses. As such, cognitive control recruitment should only reduce aggression if retaliatory impulses have been elicited in the first place. The second purpose of this investigation was to test this idea. We predicted that the cognitive modification procedure would reduce aggression specifically for participants prone to hostile attributions.

A plethora of research now indicates hostile attributions represent a relatively automatic process involved in the elicitation of aggressive impulses (see Wilkowski & Robinson, 2008a, for a review). A stable tendency to attribute hostile intent to others in ambiguous situations is associated with increased trait anger (e.g., Graham, Hudley, & Williams, 1992) and trait aggression (Orobio de Castro, Veerman, Koops, Bosch, & Monshouwer, 2002).

More recent research shows that this is a relatively automatic process. Priming hostile attributions automatically increases anger and aggression (Meier & Robinson, 2004; Neumann, 2000). Hostile attributions remain associated with anger and aggression even under cognitive load (Hazebroek, Howells, & Day, 2001). Finally, several studies indicate that implicit measures of *spontaneous* hostile attributions predict anger and aggression (Wilkowski & Robinson, 2010b; Zelli, Huesmann, & Cervone, 1995).

THE CURRENT STUDY

In summary, we predicted that our cognitive modification procedure would encourage cognitive control recruitment and reduce aggression for individuals prone to hostile attributions. We made no strong predictions regarding the effect of the cognitive modification procedure at low hostile attributions (i.e., a weaker reduction; no effect; or even a reversal; see discussion section for elaboration). To test our predictions, participants were first randomly assigned to either a cognitive modification condition or a non-modification control condition. Following this, they completed a well-validated laboratory measure of aggression (i.e., Taylor's, 1967, competitive RT task), as well as a measure of hostile attributional tendencies.

METHOD

Participants

One-hundred and eight undergraduate psychology students (70 females; *M* age = 19.9) from the University of Wyoming participated in exchange for course credit.

Apparatus

All participants completed the study on one of nine Windows-based computers using E-Prime software (version 2.0). These computers were equipped with a specially altered EmpiriSoft keyboard capable of recording RTs with less than 1 ms input-related error. The display screen had a refresh rate of 59 Hz.

Procedure

Participants arrived at the laboratory and were guided to a computer located in one of two rooms. To facilitate the deception involved in the competitive RT task (see below), participants were placed in different rooms on an alternating basis. If there was only one participant in a session, they were led to believe that other participants were completing the study in the other room (e.g., the experimenter read instructions to an empty room). As a result, participants were generally unaware of how many participants were in a session and the identity of their opponent.

Participants were told that they were completing two separate studies related to cognition and interpersonal behaviour, respectively. After providing consent, the computer program randomly assigned them to either the cognitive modification or the non-modification condition and they completed the primed flanker task for those conditions. Participants then completed the competitive RT task measure of aggression, followed by a series of questionnaires containing hostile attribution and revenge motivation scales. Once participants completed the study, the experimenter debriefed all deceptions, and they were dismissed.

Primed flanker task

Practice trials

Participants first completed 40 practice trials of the flanker task. Past research has suggested that cognitive control is used to override automatic aggressive *responses* (Wilkowski et al., 2010). Accordingly, we used a version of the flanker task which asks participants to override automatic *responses* and removes the need to exert control at earlier, perceptual stages of processing (Eriksen & Hoffman, 1973). As such, the central letter was always perceptually incongruent with the flanker letters (i.e., they were always different letters). Nonetheless, congruent trials contained two letters calling for the same response, while incongruent trials contained two letters calling for opposite responses.

To achieve this, four letters were used as stimuli (A, S, K and L). Participants pressed the left arrow key if the central letter was A or S and the right arrow key if the central letter was K or L.

Both speed and accuracy were emphasised. On congruent trials, the central and flanker letters were different but called for the same response (stimuli = AASAA, SSASS, KKLKK and LLKLL). On incongruent trials, the central and flanker letters called for opposite responses (stimuli = KKAKK, LLSLL, AAKAA and SSLSS).

Participants completed 20 congruent and 20 incongruent trials in a random order. The stimulus was presented at centre screen, and response mappings were displayed. There was a 1000 ms pause following each response. If the participant responded incorrectly, they received an error message.

Instructions to participants

Following the practice trials, participants were told that they would begin the main task. In it, a hostile or non-hostile prime word was presented before each flanker stimulus. Non-hostile words came from the coherent but affectively neutral category of cleaning actions. Participants' job was to determine which category the prime belonged to by pressing either the left or right arrow key. Response mappings were counter-balanced across participants (i.e., left = hostile for some; right = hostile for others).

The difference between congruent and incongruent trials was next explained to participants using examples from the practice trials. Participants in the cognitive modification condition were then told:

> Whenever you see a cleaning-related word, it is highly likely that a matching responses trial (where the letters both indicate the same response; "AASAA") will happen next on the flanker task. When this happens, respond quickly on the flanker task with your first impression, because it is likely to be correct. Whenever you see an aggression-related word, it is highly likely that a mismatching responses trial (where the letters indicate different responses; "LLSLL") will happen next on the flanker task. When this happens, make sure you are responding to the center letter directly. Do NOT respond quickly with your first impression, because it is quite likely to be wrong.

These instructions were modelled after similar instructions from past research (Ghinescu et al., 2010; Gratton et al., 1992). They were designed to discourage participants from acting upon automatically activated responses following hostile primes. As a result of such instructions, participants typically slow their responses on congruent trials. More interestingly, though, participants can frequently respond faster on incongruent trials, precisely because automatically activated responses are incorrect in this context. The collective result is that the flanker interference effect becomes smaller when such instructions are given (Ghinescu et al., 2010; Gratton et al., 1992).

Participants in the non-modification condition were told:

> We want to emphasize that there will be absolutely no relationship between the type of word you see on a trial (i.e., either cleaning-related or aggression-related) and the type of trial that occurs on the flanker task (i.e., either matching responses or mismatching responses). Thus, there is no reason to try to use different strategies following the cleaning-related words versus the aggression-related words to improve your performance.

These instructions were also modelled after past research (Gratton et al., 1992).

Target trials

All participants next completed 300 trials of the primed flanker task. Across both conditions, these trials involved an equal number of hostile and non-hostile primes (150 trials each) and an equal number of congruent and incongruent flanker trials (again, 150 trials each). In the non-modification condition, congruent and incongruent flanker trials were equally likely to occur following each prime type (i.e., 75 congruent and 75 incongruent trials following each prime type). In the cognitive modification condition, however, incongruent trials were more frequent following hostile primes (i.e., 120 incongruent and 30 congruent trials). Following non-hostile primes, these contingencies were reversed and congruent trials were more frequent (i.e., 120 congruent and 30 incongruent trials). This reversal following non-hostile primes ensured that the overall frequency of incongruent trials was held constant across the cognitive modification and non-modification conditions. Thus, the overall level of cognitive control usage was held constant across conditions.

All stimuli were presented in a random order. The prime was first presented at centre screen, along with response mappings. Hostile words consisted of argue, assault, demean, harm, harass, hurt, kick, punch, shove and torment. Non-hostile words consisted of bathe, brush, mop, neaten, polish, rinse, scrub, shower, sweep and vacuum. Prime words were matched in terms of word length (aggressive M = 5.3; non-aggressive M = 5.2), word frequency (aggressive M = 13.5; non-aggressive M = 15.6), part of speech (i.e., all stimuli were verbs) and category coherence (i.e., control words came from the equally coherent, neutral category of cleaning actions). T-tests confirmed that the categories did not differ in word length or frequency, ps > .70.

If participants categorised the prime word incorrectly, a 1000 ms error message was presented, and participants were asked to re-categorise the word correctly. This design feature ensures that the participant correctly identifies the prime's meaning before proceeding to the flanker task. When participants categorised the prime correctly, there was a 1000 ms pause until the presentation of the flanker stimulus. All procedures for the flanker task were identical to those used during the practice trials.

Preparation of RT data

RTs for the primed flanker task were prepared according to procedures used in past studies (Wilkowski & Robinson, 2008b). Flanker RTs involving an error were discarded (4.93% of trials). To correct for a positively skewed distribution (initial skew = 16.5; SE = .01), RTs were log-transformed. To correct for outliers, all RTs 2.5 SDs above or below the mean were windsorised (2.12% of trials). While analyses were conducted using these values, descriptive statistics are reported in terms of the original millisecond value for ease of interpretation. The skew of the resulting distribution was dramatically reduced (skew = .46; SE of the skew = .01; M RT = 820 ms; SD = 308; minimum RT = 310; maximum RT = 1955).

Competitive reaction time task

To measure aggression, participants next completed the competitive RT task (Taylor, 1967). In it, participants were told that they were competing with another participant in the opposite room to respond to a tone as quickly as possible. Each participant was allowed to select an aversive blast of white noise to administer to their opponent if they won. The selection of higher-intensity noise blasts serves as a well-validated measure of aggression (Bushman & Anderson, 1998; Giancola & Parrott, 2008; Giancola & Zeichner, 1995).

Participants completed 25 trials. On each trial, participants first selected the noise intensity to be administered to their opponent if they won. They selected from nine intensities of white noise, ranging from 60 dBA to 100 dBA in 5 dBA intervals. There was also a non-aggressive, no-noise option. For ease of interpretation, noise intensity selections were coded along a 0 (no noise) to 9 (100 dBA) scale.

A message was then displayed telling participants to wait for their opponent. This "wait for your opponent" message was displayed for 4000, 2000 or 0 ms (random) to create the appearance of a realistic opponent. Next, a message instructed participants to get ready to press the spacebar. This "get ready" message was displayed for 2000, 1500 or 1000 ms (random) to create the appearance of a difficult RT task. If the participant pressed the spacebar prior to the beep, an error message told them to wait for the beep. The beep was then played to the participant through their headphones, and they were given 750 ms to respond. A 1000 ms pause followed.

A 2500 ms message informed the participant of the outcome of the trial and the noise intensity that the loser would receive. On lost trials, participants then received the noise blast for 1000 ms. On trials which the participant won, participants received a 1000 ms message indicating their opponent was receiving the noise blast. A 1000 ms pause followed all trials.

In reality, the participant was not competing against an opponent. Instead, the outcome of each trial (win vs. loss) and the noise intensities selected by the ostensible opponent were controlled by the computer. Participants always lost the first trial. By default, participants randomly won half of the remaining trials and lost the remaining half of trials. To support the deception, however, these default settings were overridden if the participant responded extremely slowly on the RT competition. Specifically, they lost whenever they responded slower than 750 ms.

Given our focus on ambiguously hostile situations, the ostensible opponent was programmed to act in an ambiguous manner (Anderson et al., 2004). The opponent's noise selections varied widely and were delivered in a random order. Participants received each of the following noise intensities in a random order on pre-designated loss trials: 70 dBA, 75 dBA, 75 dBA, 80 dBA, 80 dBA, 85 dBA, 85 dBA, 90 dBA, 90 dBA, 95 dBA, 95 dBA, 100 dBA. If the participants responded extremely slowly on a pre-designated win trial, they received an 85 dBA noise blast.

Following this task, participants completed a full funnel probe for suspicion (Bargh & Chartrand, 2000). In it, their beliefs concerning the existence of their opponent and the hypothesis were subtly probed without overtly revealing either the deception or the hypothesis. To achieve this, participant answered four open-ended questions on the computer. Ten participants indicated some suspicion that their opponent was not real. These participants were excluded from all analyses. One additional participant (in the experimental condition) indicated that the primed flanker task may have got them "in the habit of thinking before pressing the buttons" and may have altered their behaviour on the competitive RT task (in an unspecified manner). To conservatively ensure results were not due to demand characteristics, this participant was also removed from all analyses. We would like to note that all results are virtually identical if this one participant is included in analyses. These exclusions resulted in an effective sample size of 98 participants.

Hostile attributions

Participants next completed a series of questionnaires, including a standardised measure of hostile attributions in ambiguous situations (Coccaro, Noblett, & McCloskey, 2009). Additional measures were administered for exploratory purposes.[1] The hostile attribution measure contains eight vignettes which describe another person harming the participant. Across all scenarios, it is unclear whether the harm-doer intended to harm the participant or not. For example, one scenario involves a person cutting in front of the participant in line at a coffee store.

After each scenario, participants were presented with four viable attributions for the harm-doer's behaviour. Two of these attributions were hostile (e.g., this person wanted to make you wait longer), while the remaining attributions were benevolent (e.g., this person did not realise they cut in front of you) or instrumental (e.g., this person was in a hurry to get to work). Participants rated how likely each explanation was, using a 0 (not at all likely) to 3 (very likely) scale. While all items were administered, we were critically interested in participants' responses to the hostile attribution items. Following Coccaro et al.' s (2009) recommendations, participants' responses to the 16 hostile attribution items were averaged to form a single score (M = 1.06; SD = .44; minimum = .06; maximum = 2.13).

[1] The Aggression Questionnaire (Buss & Perry, 1992), the Displaced Aggression Questionnaire (Denson, Pedersen, & Miller, 2006), the Emotion Regulation Questionnaire (Gross & John 2003) and the trait anger subscale of the State-Trait Anger Expression Inventory (Spielberger, 1988) were administered for exploratory purposes. Unlike hostile attributions, none of these scales measures an automatic process involved in anger elicitation. Thus, none provides a clear test of the hypothesis.

Coccaro et al. (2009) provided extensive evidence for this scale's reliability and validity. It is significantly related to trait aggression. Impulsive-aggressive in-patients score higher than healthy controls on this instrument, and it exhibits strong test–retest reliability. This scale is also internally reliable (in the current study: α = .86).

Motivations during the competitive RT task

Based on prior research (Graham et al., 1992; Wilkowski & Robinson, 2010b), we theorised that hostile attributions lead to the elicitation of revenge motivation. To test this assumption, we also administered a scale measuring participants' revenge and compassionate goals during the competitive RT task. Nine items adapted from past research (Anderson & Murphy, 2003; McCullough et al., 1998; "I wanted to get even with my opponent".) measured revenge motivation. Five items (e.g., "I wanted to have compassion towards my opponent".) adapted from Canevello and Crocker (2010) measured compassionate motivation. Both measures were internally reliable (αs > .72). Revenge motivation was also significantly correlated with noise intensity selections, r = .47, p < .0001, providing evidence of its construct validity. However, compassionate goals were not significantly correlated with noise selections, $r = -.11$, p = .28. Nonetheless, we report findings using this scale in the interests of full disclosure.

RESULTS

Preliminary analyses

Initial analyses indicated that participants in the modification condition exhibited somewhat slower RTs overall (M = 841 ms; SD = 137 ms) compared to participants in the non-modification condition (M = 795 ms; SD = 131 ms), $t(95)$ = 1.64, p = .10. This effect was not entirely unexpected, as participants in the modification condition had to process the implications of the prime and adjust their strategy accordingly. Unfortunately, such group differences in overall RT can cloud the interpretation of flanker interference effects. Specifically, it could lead to the appearance of larger interference effects in the modification condition simply because this group took longer to respond overall (Faust, Balota, Spieler, & Ferraro, 1999). To correct for this, we applied a z-score transformation procedure recommended by Faust et al. Participants' overall RT on the primed flanker task was subtracted from their mean RT for each within-subject condition. The resulting difference score was then divided by the participant's standard deviation for that within-subject condition.

Flanker task RTs

We first predicted that the cognitive modification procedure would reduce the flanker interference effect following hostile primes. To test this, z-transformed flanker RTs were analysed in a 2 (prime: hostile vs. non-hostile) by 2 (congruency: incongruent vs. congruent) by 2 (modification condition: cognitive modification vs. non-modification) mixed model ANOVA. The first two factors varied on a within-subject basis, and the last factor varied on a between-subject basis. AQ4

The congruency main effect was highly significant, $F(1, 96)$ = 291, p < .0001. RTs were slower for incongruent (raw M = 856 ms; z-transformed M = .20) compared to congruent (raw M = 777 ms; z-transformed $M = -.17$) trials. The only remaining significant effect was the hypothesised three-way prime by congruency by modification condition interaction, $F(1, 96)$ = 4.58, p = .03, partial η^2 = .05; all other ps > .09. The magnitude of the flanker effect (i.e., z-transformed incongruent RT minus z-transformed congruent RT) for each condition is depicted in Figure 2. As displayed there, participants in the cognitive modification condition displayed a smaller flanker effect following hostile (compared to non-hostile) primes, $F(1, 45)$ = 4.57, p = .04. In the non-modification condition, flanker interference effects did not significantly differ across prime types, p = .47.

Further analyses suggested that relative to the non-modification condition, the cognitive modification condition reduced the flanker interference

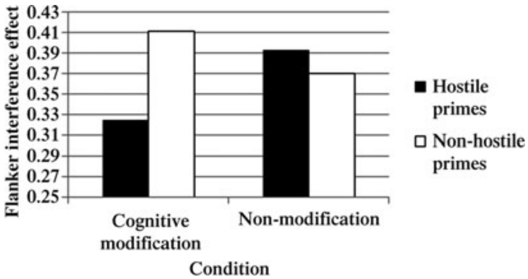

Figure 2. *Flanker interference effects as a function of prime type and modification condition.*
Note: Flanker interference effects are calculated as incongruent RT minus congruent RT. RTs have been *z*-transformed to control for group differences in overall RT.

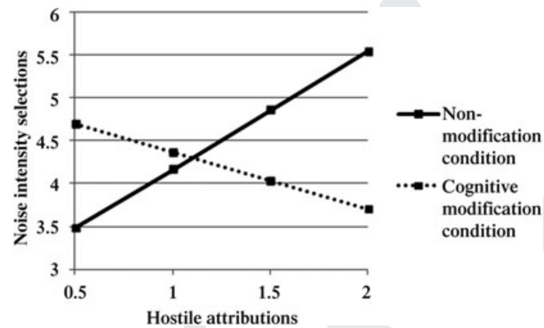

Figure 3. *Noise intensity selections as a function of hostile attributions and modification condition.*
Note: Hostile attribution represents a participant's average likelihood rating for hostile explanations of ambiguously hostile action on a 0 (0 (not at all likely) to 3 (very likely) scale.

effect following hostile primes, although this effect did not reach significance, $F(1, 95) = 1.95$, $p = .16$. In contrast, the modification condition had no significant effect on flanker interference effects following non-hostile primes, $p = .43$. These results suggest that the cognitive modification procedure successfully encouraged participants to recruit cognitive control resources following hostile primes.

Aggressive behaviour

We next predicted that the cognitive modification procedure would reduce aggression for participants prone to hostile attributions. To test this, participants' average noise intensity selections were examined in a multiple regression. Modification condition (coded modification = 1; non-modification = −1) and participants' standardised hostile attribution scores were entered as predictors in the first step. The interaction term was entered in the second step.

The main effect of both modification condition and hostile attributions was non-significant, ps > .40. More importantly, the predicted modification condition by hostile attributions interaction was significant, $\beta = -.25$, $p = .02$. To de-compose this interaction, we used the well-validated mean estimation procedures introduced by Aiken and West (1991). Mean noise intensity selection was separately estimated at different levels of hostile attributions in each modification condition. To illustrate the nature of the effect across the entire continuum of hostile attribution scores, we estimated these values at every .5 interval on the raw scale within the obtained data range. These resulting values are displayed in Figure 3.

As displayed there, hostile attributions were significantly and positively related to noise intensity selections in the non-modification condition, $\beta = .33$, $p = .01$. However, this relationship was rendered non-significant within the cognitive modification condition, $\beta = -.16$, $p = .31$. Thus, the cognitive modification procedure eliminated the effect of hostile attributions on aggression.

We next conducted a region of significance analysis (Preacher, Curran, & Bauer, 2006) to determine the precise level of hostile attributions at which the cognitive modification procedure significantly altered participants' noise intensity selections. This analysis indicated that at 1.8 SDs above the mean hostile attribution score (i.e., approximately 1.9 on the raw scale), the cognitive modification procedure significantly reduced participants' noise intensity selections, $b = -.76$, $p < .05$ (non-modification condition: $M = 5.32$; modification condition: $M = 3.80$). Thus, the cognitive modification procedure significantly reduced aggression for participants strongly prone to hostile attributions.

Interestingly, though this analysis indicated that at 1.1 SDs below the mean hostile attribution score (i.e., approximately .6 on the raw scale), the cognitive modification procedure significantly *increased* noise intensity selections, [illegible] = .53, p = .05 (non-modification condition: M = [illegible]8; modification condition: M = 4.64). We discuss possible explanations for this in the discussion.

Hostile attributions and the elicitation of revenge goals

Based on past research (e.g., Graham et al., 1992; Wilkowski & Robinson, 2010b), we suggested that hostile attributions are involved in the elicitation of revenge motivation and the reduction of compassionate motivation. To test whether this is true, two regression analyses were conducted predicting revenge and compassionate motivation. Hostile attributions and modification condition were entered as predictors in the first step, and their interaction term was entered in the second step. No strong predictions were made regarding the modification procedure's effects in these analyses.

Consistent with expectations, hostile attributions were significantly related to higher revenge motivation, β = .23, p = .02, and lower compassionate motivation, β = −.24, p = .02. The modification condition main effects and the hostile attribution by modification condition interactions were non-significant in both analyses, ps > .10. Thus, hostile attributions evoked revenge motivation and reduced compassionate motivation, but the cognitive modification procedure did not significantly affect this outcome. This suggests that the cognitive modification procedure intervened between the elicitation of revenge motivation and the execution of actual aggressive actions in some manner.

The independence of hostile attributions and cognitive control recruitment

Although hostile attributions and cognitive control recruitment are both related to trait anger and retaliatory aggression, we view them as independent processes (Wilkowski & Robinson, 2008a). As such, we did not expect hostile attributions to be related to cognitive control recruitment in any manner. Theoretically, this is interesting to establish in and of itself. Methodologically, it is important to show that the cognitive modification procedure was not differentially effective at different levels of hostile attributions. This would establish the legitimacy of treating hostile attributions and modification condition as separate variables in the analyses above.

A subsequent General Linear Model analysis of flanker task RTs provided evidence in support of this. In this analysis, participants' standardised hostile attribution scores were added as a continuous between-subject factor to the original analysis of flanker RTs. This analysis replicated all the original findings reported above. More importantly, it indicated that hostile attributions did not alter the effectiveness of the cognitive modification procedure. The three-way prime by congruency by hostile attribution interaction and the four-way prime by congruency by modification procedure by hostile attribution interaction were both non-significant, p > .71.

Conversely, it is important to establish that the cognitive modification procedure did not alter participants' tendencies towards hostile attributions. Consistent with expectations, the modification condition (M = 1.01) and the non-modification condition (M = 1.10) did not differ in hostile attribution scores, t (95) = .95, p = .34. Theoretically, this indicates that hostile attributions and cognitive control recruitment are independent processes. Methodologically, this establishes that it was appropriate to treat hostile attributions and modification condition as separate variables in the main analyses above.

DISCUSSION

Summary of predictions and results

A recent model (Wilkowski & Robinson, 2008a) proposes that recruiting cognitive control resources following exposure to hostile stimuli should allow individuals to more effectively override their aggressive impulses. If true, then practice with this cognitive procedure should allow individuals to more effectively regulate their aggressive impulses. The current study was designed to test this prediction.

To do so, we developed a cognitive modification procedure in which participants frequently encountered incongruent flanker stimuli following hostile primes. Because incongruent flanker stimuli require participants to override automatic responses (Coles et al., 1985), this should in effect teach participants to recruit cognitive control resources when encountering hostile stimuli. We compared this to a non-modification condition in which congruent and incongruent stimuli were equally likely following hostile primes.

Results were largely consistent with predictions. Participants in the modification condition exhibited a reduced flanker effect following hostile primes, while participants in the non-modification condition displayed no such effect. Thus, the cognitive modification procedure successfully encouraged cognitive control recruitment.

Furthermore, there was evidence that the cognitive modification procedure encouraged participants to override retaliatory impulses. Participants who were prone to hostile attributions also became strongly revenge-motivated during the competitive RT task. We therefore predicted that the cognitive modification procedure would allow these individuals to override their aggressive impulses. Consistent with this, hostile attributions predicted higher noise intensity selections within the non-modification condition. However, this relationship was rendered non-significant within the cognitive modification condition. Further, region-of-significance analyses indicated that this was due in part to the cognitive modification procedure reducing aggression among individuals highly prone to hostile attributions.

Interestingly, region-of-significance analyses also indicated that the cognitive modification procedure increased aggression among individuals less prone to hostile attributions. While this effect was clearly significant, we would like to emphasise that it is independent of the significant hypothesised effect and does not undermine it. Nonetheless, this effect does provide important qualifications to the hypothesised finding, and it of course warrants theoretical explanation of its own. We now turn to a discussion of these issues.

Overriding non-hostile urges?

At a purely descriptive level, our cognitive modification procedure encourages participants to override pre-potent responses when hostile thoughts are activated. It is important to emphasise that the nature of the responses is not specified. Indeed, the responses used in the flanker task (i.e., keyboard presses) are completely non-aggressive in nature.

This opens up the possibility that—at least under certain circumstances—the cognitive modification procedure may encourage people to override *non-hostile urges*. If so, this procedure would actually result in people behaving *more* aggressively. We propose that the increased aggression displayed by low hostile attribution participants in the cognitive modification condition represents an instance of overriding non-hostile urges.

First, post-task questionnaires indicated that participants low in hostile attributional tendencies were not motivated to retaliate against their opponents. This is consistent with past research indicating that individuals low in hostile attributions do not become angry or aggressive in ambiguously hostile situations (Graham et al., 1992).

In the absence of *hostile urges*, recent theories suggest that *non-hostile urges* may predominate. Under such circumstances, models of moral judgement suggest that people possess an automatic aversion to harming others (Cushman & Greene, 2012). These emotional intuitions often lead people to be unwilling to harm one person even when it would result in larger benefits (e.g., killing 1 person to save 10 people; Cushman, Gray, Gaffey, & Mendes, 2012; Greene et al., 2009).

Interestingly, these same models suggest that cognitive control resources can be used to override this non-hostile aversion to harm. Moore, Clark, and Kane, (2008) found that people with superior cognitive control abilities sometimes find it more acceptable to kill one person in order to save more lives. Similarly, Paxton, Ungar, and Greene (2012) found that an experimental manipulation of cognitive control recruitment led participants to be more willing to kill one person to save many.

In the current study, it is therefore possible that the cognitive modification procedure led low hostile attribution participants to override their aversion to harm, ultimately resulting in more aggression. In the context of a RT competition, participants may have viewed such actions as useful towards the goal of winning the competition. If true, this suggests that self-control may have a dark side. It may sometimes allow people to overcome doubts and anxieties in order to behave aggressively. We are currently conducting studies testing this prediction more directly.

Overriding hostile urges

Beyond this non-hypothesised finding, the current study provided support for a recently proposed model of anger regulation (Wilkowski & Robinson, 2008a). According to this model, cognitive control must be recruited following exposure to hostile stimuli to control one's aggressive impulses. As such, practice recruiting cognitive control in such circumstances should allow individuals to more effectively control their aggressive impulses.

The current investigation provides support for this theory. First, it provides preliminary evidence that cognitive control recruitment *causes* a decrease in aggression. Cognitive modification procedures were originally developed to provide researchers with a way of testing whether information-processing patterns have a causal influence (MacLeod & Mathews, 2012). The current study developed a novel cognitive modification procedure and showed it significantly influences cognitive control recruitment. More importantly, this study demonstrated that this procedure allows individuals to override aggressive impulses.

Second, this study provided further evidence that cognitive control recruitment affects the *regulation* of aggressive impulses. Past research has supported this idea by linking cognitive control recruitment to the effortful process of forgiveness (Wilkowski et al., 2010). The current study provides a separate and converging source of evidence for this same conclusion. It specifically shows that cognitive control recruitment helps to override more automatic processes promoting aggression (i.e., hostile attributions). Future research should further examine this idea by experimentally manipulating automatic hostile attributions (e.g., Neumann's, 2000, priming procedure).

Future directions

Future research should seek to rule out possible alternative explanations for these effects, such as ego depletion (Baumeister, Vohs, & Tice, 2007). After all, incongruency in Stroop-like tasks is a well-validated means of depleting self-control resources (Hagger, Stiff, Wood, & Chatzisarantis, 2010). In the current study, we carefully controlled for this possibility by equating the number of incongruent trials across the modification and non-modification conditions. Nonetheless, it remains possible that the strategic use of cognitive control resources may affect the availability of these resources in a more subtle fashion. The proactive recruitment of cognitive control resources in the modification condition may have eased ego depletion effects in some way. Alternatively, forcing participants in this condition to rapidly alternate between different strategies may have itself been depleting (Hamilton, Vohs, Sellier, & Meyvis, 2011).

We therefore suggest that future researchers employ a control condition in which participants are encouraged to recruit cognitive control resources following non-hostile primes. This would more stringently equate the availability of resources across conditions. Furthermore, it would demonstrate that cognitive control resources must be recruited in hostile situations specifically in order to regulate aggressive impulses.

Past research suggests that forgiveness is one mechanism underlying cognitive control recruitment's effects on anger and aggression (Wilkowski et al., 2010). The current study was not designed to test this prediction. Nonetheless, we encourage future research to investigate whether the effects of this cognitive modification procedure are due to forgiveness.

Finally, future research should examine whether the current effects generalise to other measures of aggression or to longer time scales. The competitive RT task used in the current study is certainly well-validated (e.g., Giancola & Parrott, 2008). Nonetheless, it focuses on aggression within competitive contexts specifically. It will be important to determine if the procedure can reduce aggressive in non-competitive contexts.

Finally, past research on other cognitive modification procedures suggests that repeated administrations should have long-term effects (MacLeod & Matthews, 2012). We would therefore predict that the repeated administration of this procedure would lead to longer-lasting reductions in aggression.

Broader implications

Clinical researchers contend that cognitive modification procedures may be useful in the treatment of clinical disorders (MacLeod & Mathews, 2012). We wholeheartedly agree that well-developed cognitive modification procedures (e.g., attention re-training for anxiety) have reached the point where such recommendations deserve serious attention. However, our cognitive modification procedure is at a very early stage of development, and its use in treatment is clearly not yet warranted. This procedure led to increased aggression for some participants (i.e., those low in hostile attributions). Researchers should therefore develop procedures which avoid this side-effect or direct this procedure towards individuals who should exhibit reduced aggression following its use (i.e., those high in hostile attributions). Nonetheless, we are hopeful that given adequate time for development, cognitive control modification procedures may have practical benefit for the treatment of anger disorders.

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