Due Diligence: Revisiting the Heat-Aggression Association Hypothesis

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This research was partially supported by a small research grant awarded to the author from the Society for Personality and Social Psychology.

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Abstract

Previous research has asserted that individuals hold cognitive associations between the constructs of hot temperatures and aggression (e.g., DeWall & Bushman, 2009). However, subsequent studies have cast doubt on whether these previously-used methods reliably produce effects that support this assertion (e.g., McCarthy, 2014). Thus, the evidence for the existence of a cognitive heat-aggression association is mixed. To test for this hypothetical association using a different method, and to address shortcomings in the previously-used methods, the current studies used a modified Affect Misattribution Procedure (e.g., Payne, Cheng, Govorun, & Stewart, 2005) to examine whether exposure to heat-related words increased the accessibility of aggressive cognitions. Both a pilot study and a Registered Report showed that exposure to heat-related words increased the accessibility of aggressive cognitions. However, exposure to cold-related words also, and unexpectedly, increased the accessibility of aggressive cognitions. And these results were only found for participants who reported that the primes influenced their Misattribution Task performance. Thus, although the current results found that exposure to heat-related stimuli caused theoretically-predicted effects, the overall evidence is somewhat mixed as to whether this is due to a cognitive association between hot temperatures and aggression.

Keywords: replication; aggression; aggressive cognitions; hot temperatures

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Experiencing hot temperatures is associated with behaving aggressively (e.g., C. A. Anderson, Anderson, Dorr, DeNeve, & Flanagan, 2000; Van Lange, Rinderu, & Bushman, 2017). In examining why experiencing hot temperatures may cause aggressive behaviors, some researchers hypothesized that individuals hold a cognitive association between the concepts of *hot temperatures* and *aggression* (e.g., DeWall & Bushman, 2009). The implication is that experiencing hot temperatures may cause aggressive behaviors via a cognitive process involving a heat-aggression association. Although evidence for this heat-aggression association hypothesis garnered initial empirical support in two studies by DeWall and Bushman (2009), the replicability of those effects has been questioned (e.g., McCarthy, 2014). Nevertheless, despite doubts about the replicability of the effect, some researchers continue to assume the heat-aggression association hypothesis is well-established (e.g., Groves & Anderson, 2016) and have used it as an empirical foundation for proposing and testing novel hypotheses (e.g., Batra, Ghoshal, & Raghunathan, 2017).

The current research discusses the theoretical foundation of the heat-aggression association, re-examines the extant empirical evidence for the effect, and tests the heat-aggression association hypothesis using a novel approach. The current research was intended to address shortcomings in the prior research and to more robustly test the heat-aggression association hypothesis.

The Theoretical Framework of the Heat-Aggression Association

DeWall and Bushman (2009) state that “given the robust co-occurrence of hot temperatures and aggression, people develop knowledge structures in which the the link between hot temperatures and aggression become associated in memory” (p. 1046). This theoretical heat-aggression association is believed go beyond an association between actually experiencing hot temperatures and actual aggressive behaviors; rather, individuals are believed to have conceptual knowledge of the co-occurrence of hot temperatures and

aggression. This conceptual knowledge is believed to be reflected within, for example, our “sophisticated capacity to use language” (DeWall & Bushman, 2009, p. 1046). Indeed, people often use idioms such as “hot headed,” “hot under the collar,” or having a “fiery temper” to describe individuals who are likely to behave aggressively, an angry interaction is often described as “heated,” and idioms such as “cool down” and “chill out” are commonly used to describe conditions where individuals try to control their aggression. Further, people in several cultures often use metaphors of a hot fluid within a pressurized container to convey feelings of anger (e.g., “I am steaming mad,” “his blood is boiling,” “she blew up;” e.g., Kövecses, 2000).

The implication of a cognitive heat-aggression association is that exposure to heat-related stimuli may have a measureable influence on aggression-related outcomes in the absence of actually experiencing hot temperatures (e.g., DeWall & Bushman, 2009; Wilkowski, Meier, Robinson, Carter, & Feltman, 2009). Therefore, the co-occurrence of prior observations of hot temperatures and aggression, and the relatively common idioms that use the concepts of hot temperatures to convey aggressiveness, suggest it is plausible that increasing the accessibility of the cognitions related to hot temperatures could correspondingly increase the accessibility of cognitions related to aggression via the theoretical “spreading activation” of associated cognitive concepts (e.g., C. A. Anderson & Bushman, 2002).

The idea that individuals hold cognitive associations between hot temperatures and aggression also is corroborated by related research that has demonstrated that exposure to pictures of weapons (e.g., C. A. Anderson, Benjamin Jr, & Bartholow, 1998) and stimuli related to alcohol (e.g., Bartholow & Heinz, 2006)—classes of stimuli that also are theoretically associated with aggression—seem to increase the accessibility of aggressive cognitions. Therefore, one could conceptualize “hot temperatures” as merely another type of stimuli that is cognitively associated with aggression and the studies examining a heat-aggression association are specific instances of a more general program of research on

cognitive factors associated with aggressive cognitions.

The Empirical Evidence on a Heat-Aggression Association

Following the ideas presented in the previous section, DeWall and Bushman (2009) reported two experiments that tested whether individuals hold a cognitive association between hot temperatures and aggression. In both experiments, participants were randomly assigned to one of three conditions of a sentence descrambling task: A heat priming condition, a cold priming condition, or a neutral condition. The effect of interest was that participants who descrambled sentences containing heat-related words (i.e., the heat priming condition), relative to those who descrambled sentences that did not contain heat-related words (i.e., the neutral condition), would have increased accessibility of aggressive cognitions. In their Experiment 1, the accessibility of aggressive cognitions was inferred based on participants' performance in an aggressive word fragment completion task. In their Experiment 2, the accessibility of aggressive cognitions was inferred based on the extent to which participants perceived the protagonist of a vignette as being hostile.

In DeWall and Bushman (2009) Experiment 1, those in the heat priming condition completed the potentially-aggressive word fragments using aggressive words more than those in the neutral condition, $F(1, 124) = 4.16, p = .044$. In Experiment 2, those in the heat priming condition rated the protagonist as being more hostile than those in the neutral condition, $F(1, 69) = 4.23, p = .043$. Presumably, for those in the heat-priming condition, completing the priming task required the activation of heat-related semantic information, which then increased the accessibility of the associated aggression-related cognitions, which then presumably affected participants' subsequent task performance.

Despite these positive findings, these two effects each produced effects less than the traditional criterion for statistical significance of $p < .05$, but also had exact p -values that were relatively high within this range of significance. Specifically, both studies resulted in p -values that were $p < .05$ and $p > .04$ for these hypothesis-critical comparisons, which

would be rare for tests of a non-null effect (e.g., Simonsohn, Nelson, & Simmons, 2014). Further, the size of the observed effects were relatively strong compared to other priming studies (see Pashler, Coburn, & Harris, 2012 for a relevant discussion) and for the other studies using the same priming procedure (i.e., the sentence descrambling task; see DeCoster & Claypool, 2004). Finally, these priming effects presumably lasted several seconds (and possibly even several minutes), which is perhaps surprising given that priming effects due to the residual activation of semantic information are believed to decay rapidly (e.g. Wentura & Rothermund, 2014).

Given that single demonstrations of the operationalizations of the effect are insufficient to consider the effects as replicable, both hypothesis-critical effects had relatively high (albeit “significant”) p -values, and the effects were strong and consistent for the priming procedure that was used, McCarthy (2014) attempted to replicate Experiment 2 from DeWall and Bushman (2009). In these two close replication attempts, the observed effects were $d = -0.02$, 95% CI[-0.38, 0.34] and $d = 0.00$, 95% CI[-0.22, 0.22] for the critical comparison of “hostile perceptions” among those in the heat priming condition and those in the neutral condition. The effects from these replication attempts were both substantially smaller than the original effect observed in DeWall and Bushman (2009) and were interpreted as unsupportive of the heat-aggression association hypothesis.

Although the replication attempts by McCarthy (2014) tried to adhere to the original methods as closely as possible and had high statistical power to detect effects of the same magnitude as those in DeWall and Bushman (2009), the results are only discordant to the extent the replication attempts created the necessary conditions for the effect to emerge. With the absence of manipulation checks, positive controls, or a strong history of this procedure producing theory-relevant effects, it is ambiguous as to whether McCarthy (2014) successfully created these necessary conditions to detect the effects. For some, this ambiguity may have buffered the hypothesis from the threat of falsification (e.g., Greenwald, Pratkanis, Leippe, & Baumgardner, 1986; LeBel & Peters, 2011), which, it could be supposed, is why

some researchers continue to cite the original study as evidence of the effect (e.g., Groves & Anderson, 2016). Further, McCarthy (2014) only attempted to replicate one of the two experiments presented by DeWall and Bushman (2009). It may be an over-statement to infer the evidence for the heat-aggression association is non-replicable based on only two replication attempts of only one operationalization of that effect.

Overview of the Current Research

The current research tests the idea that individuals possess a cognitive association between hot temperatures and aggression. I examined two competing possibilities. On the one hand, consistent with the belief that individuals hold a cognitive association between hot temperatures and aggression, exposing individuals to “heat-related” stimuli could subsequently increase the accessibility of aggression-related cognitions as was argued by DeWall and Bushman (2009). This would mean the replication attempts by McCarthy (2014) were discordant either because of Type II errors or because the necessary conditions for the effects to emerge were not realized. On the other hand, given the questionable strength and the lack of demonstrated replicability of the initial empirical evidence for the heat-aggression association, exposing individuals to “heat-related” stimuli might not have a measureable influence on subsequent tasks that purportedly assess the accessibility of aggression-related cognitions.

In addition to testing whether individuals hold cognitive heat-aggression associations, the current research improved upon several shortcomings in prior tests of this hypothesis. First, “positive controls” were included to ensure the conditions for potentially observing a heat-aggression association were properly created. Second, because priming effects due to semantic associations are believed to decay rapidly (e.g. Wentura & Rothermund, 2014), the current research used a task that minimized the time between the exposure to the priming stimuli and the measurement of the presumed effect of that exposure. The current research’s emphasis on brief priming effects is a notable deviation from the approach taken by DeWall

and Bushman (2009) and McCarthy (2014); however, my goal was to create the best possible conditions for observing evidence for a heat-aggression association and not to faithfully replicate those previously-used methods. Finally, the word fragment completion task and the impression formation task are relatively complex outcome variables to merely test the accessibility of information. These outcomes involve, for example, the retrieval of potential solutions to the word fragments, the decision-making process to use one word over other words to complete the word fragments, the interpretation of narrative text, and the incorporation of several disparate pieces of information into judgments of the study protagonist. Because the priming manipulations could affect one or more of these cognitive sub-processes, it is difficult to discern precisely how exposure to heat-related stimuli may affect performance on these outcome tasks. Thus, the current research used an outcome task that is arguably simpler than tasks used in past research.

These improvements were accomplished using a modified Affect Misattribution Procedure (e.g., Payne et al., 2005), which I will simply refer to as the Misattribution Task herein. In this task, participants completed several trials in which they judged whether an unfamiliar stimulus connoted hostility. These stimuli were presented very quickly (i.e., 100 ms). Given the unfamiliarity of the to-be-judged stimuli and the sparse information on which to form their judgments, participants' judgments are believed to be susceptible to subtle influences such as the brief exposure to stimuli and may even misattribute the influence of ostensibly unrelated stimuli to the to-be-judged stimulus. In the current studies participants were briefly exposed to a word (i.e., 75 ms) prior to making each judgment. Some of these were heat-related words and some were non-heat-related words. The logic of the Misattribution Task is simple: If exposure to heat-related words increases the accessibility of aggressive cognitions, and this accessibility is misattributed to the to-be-judged stimuli, then the unfamiliar stimuli should be judged as more aggressive when preceded by heat-related stimuli.

The benefits of the Misattribution Task are fourfold. First, because the words that

precede the judgments can vary from trial-to-trial, the critical hypothesis that heat-related words increase the accessibility of aggressive cognitions can be tested in a highly repeated-measures, within-participants design. This design will have greater statistical power to detect the effect (on a per-participant basis) than the between-participants designs of the prior research by DeWall and Bushman (2009) and McCarthy (2014). Second, the proposed design can incorporate “positive controls” to ensure the necessary conditions to observe the theoretically predicted effects are realized, which allows for stronger inferences to be made about the central hypotheses (e.g., Gawronski & Bodenhausen, 2015). Third, there is very little time between the exposure to heat-related stimuli and the aggression-related judgments, which should increase the likelihood of detecting the fleeting influence of the exposure to stimuli. Finally, the outcome task is a relatively simple perceptual judgment as opposed to the relatively complex outcomes used in DeWall and Bushman (2009) and McCarthy (2014). Therefore, *if* individuals possess cognitive associations between hot temperatures and aggression, *then* the brief exposure to heat-related words should systematically influence participants’ judgments during the Misattribution Task such that they judge the unfamiliar stimuli as more aggressive.

All stimuli, data, and R code can be obtained at this project’s Open Science Framework page (<https://osf.io/ptmn6/>) or by contacting the author.

Pilot Study of a Novel Approach to Testing the Heat-Aggression Association

A pilot study was first conducted to demonstrate the utility of the Misattribution Task, to ensure that participants properly understood the instructions, that the data were properly recorded, etc. The hypotheses for the heat-aggression portion of the pilot study were pre-registered at aspredicted.org prior to data collection (<https://aspredicted.org/sr37g.pdf>).

Procedure

Participants completed the pilot study as part of a larger study session on aggression and social interactions (a description of the entire study session is available as a

supplemental file on this project’s OSF page). When participants reached the heat-aggression association portion of their study session, participants were told they would complete a computer-based task where they intuit the meaning of several Chinese ideographs. Specifically, participants were told they would briefly view a series of Chinese ideographs and that some of those ideographs were “hostile” words and some were “friendly” words. For each trial, participants’ task was to intuit the meaning of each ideograph using a scale ranging from *1-very friendly* to *4-very hostile* (c.f., Payne et al., 2013, Study 2).

Prior to the presentation of each Chinese ideograph, participants were briefly presented with one of six different types of words: Hostile words, kind words, heat-related words, cold-related words, neutral (i.e., non-temperature-related) words, and non-word letter strings (e.g., “slon”). The type of word preceding the Chinese ideograph defined the trial type variable in the analyses below. The first four trial types are relevant to constructs of interest, the latter two trial types served as useful comparisons.

There were six words for each of the six trial types. The six *hostile* words were hostile, mean, rude, fight, hurt, and hate. The six *kind* words were friendly, nice, kind, smile, love, and like. The six *heat*-related words were sunburn, boil, roast, hot, sweat, and burn. The six *cold*-related words were frostbite, freeze, defrost, cold, shiver, and frozen. These heat-related and cold-related words were the same words as those in the priming task from DeWall and Bushman (2009). The six *neutral* words were table, desk, ball, stand, shoe, and wall. Finally, the six *non-word* letter strings were *torg*, *reen*, *slon*, *elag*, *trem*, and *wath*. Each of these words was shown prior to the Chinese ideograph on 2 trials. This means there were (6 words $\times$ 2 trials) 12 trials for each trial type and (12 trials for each trial type $\times$ 6 trial types) 72 trials overall.

The stimuli for each trial had the following presentation times. In the center of the screen, a randomly-selected word from one of the six trial type lists was shown for 75ms, a blank screen for 125 ms, and a randomly-selected Chinese ideograph for 100 ms. Then a post-mask (a square of random, black-and-white pixels) appeared in the center of the screen

where the previous stimuli were shown and the rating scale appeared on the bottom of the screen until a participant responded. These presentation times are typical for this task (e.g., Payne et al., 2005) and the stimuli are not, nor are they intended to be, subliminal. Once a participant provided their judgment of the Chinese ideograph, the next trial automatically began.

The type of word, the Chinese ideograph, and the word-Chinese ideograph pairing were randomized by the computer for each participant. Thus, any unique stimuli, order of stimuli, or pairing of stimuli could not have systematically affected the overall results.

After providing their last judgment, participants responded whether they speak Chinese and whether they knew the meaning of any of the Chinese ideographs they saw. Further, at different points during the overall study session, participants responded to three Instructional Manipulation Checks (Oppenheimer, Meyvis, & Davidenko, 2009). These yes/no questions were “*I speak every language in the world,*” “*I was born before the year 1900,*” and “*I am a human who can read*” and were included to test whether participants were paying attention.

At the end of the study, participants provided demographic information, were debriefed, thanked, and compensated before being dismissed.

Participants

There were 111 participants who started the study. Shortly into the data collection efforts, we realized that one research assistant was inadvertently stopping the study sessions prior to the Misattribution Task. Thus, some participants who started the overall study did not contribute data to the current pilot study. Of the 89 participants who completed the Misattribution Task, 20 participants failed a manipulation check (i.e., they reported speaking Chinese or knowing the meaning of one or more Chinese ideographs, or they failed one of the Instructional Manipulation Check items) and were omitted from all analyses. This left a final sample of 69 participants.

In the final sample, 36 participants were male and 33 were female. The average age of participants in the final sample was 20.01 ($SD = 2.55$) years.

Results

Analytic Approach

Participants' Misattribution Task performance was analyzed using multi-level regression with the 72 individual trials (modeled at Level 1) nested within individual participants (modeled at Level 2). The judgment of "hostility" for each trial type was the dependent variable. Slopes and intercepts were allowed to vary randomly in all of the analyses presented below. For analyses, I used the lme4 package in R (i.e., Bates, Mächler, Bolker, & Walker, 2015).

Contrast effects coding was used to test the hypotheses of interest. First, four contrast codes were created to separately compare the hostile-word trials, kind-word trials, heat-word trials, and cold-word trials to the average of the neutral and nonsense trials. For each contrast, this was accomplished by applying a weight of +0.667 to critical trial type, a weight of 0 to the non-critical trial types, and weights of -0.333 for the neutral and nonsense trials, respectively. For example, the contrast code for the heat-word trials used weights of 0, 0, +0.667, 0, -0.333, and -0.333 for the hostile, kind, hot, cold, neutral, and nonsense trials, respectively. A positive coefficient would indicate that participants rated the Chinese ideograph as more aggressive on trials when the ideographs were preceded by heat-related words relative to the control trials (i.e., the mean of the neutral-word trials and nonsense-word trials).

A final contrast applied weights of 0, 0, 0, 0, +0.5, and -0.5 to the hostile, kind, hot, cold, neutral, and nonsense trials, respectively. This contrast compared the ratings of the Chinese ideographs on the neutral-word trials and nonsense-word trials to ensure they both affected ratings of aggressiveness to a similar degree.

As an initial look at the data, participants' average judgment of "aggressiveness" of the

Chinese ideographs were computed separately for the hostile-word trials ($M = 3.07$, $SD = 0.64$), kind-word trials ($M = 1.68$, $SD = 0.58$), heat-word trials ($M = 2.53$, $SD = 0.51$), cold-word trials ($M = 2.50$, $SD = 0.54$), neutral-word trials ($M = 2.08$, $SD = 0.50$), and the nonsense-word trials ($M = 2.43$, $SD = 0.48$). These means are displayed in Figure 1.

Testing the Heat-Aggression Association Hypothesis

To demonstrate the methods were appropriate for potentially detecting the effect of interest, the contrast code for the hostile-word trials was positive and significant, $b = 1.03$, ($SE = 0.10$), $p < .001$; and the contrast code for the kind-word trials was negative and significant, $b = -1.05$, ($SE = 0.11$), $p < .001$. Thus, relative to the average of the neutral-word trials and nonsense-word trials, participants rated the Chinese ideographs as more aggressive when preceded by hostile words and less aggressive when preceded by kind words. Further, a contrast compared the the neutral-word trials and the non-sense word trials, $b = -0.35$, ($SE = 0.07$), $p < .001$. Unexpectedly, the Chinese ideographs were rated as more aggressive when preceded by non-sense words than when preceded by neutral words.

The contrast for heat-word trials was positive and significant, $b = 0.22$, ($SE = 0.06$), $p < .001$. Even though the magnitude of the coefficient is small relative to the positive controls, this effect is in the hypothesized direction. However, unexpectedly, the contrast for cold-word trials was also positive and significant, $b = 0.18$, ($SE = 0.06$), $p = .003$.

Exploratory Analyses

During the initial review, a reviewer suggested conducting the multi-level regression analysis using a dummy coding scheme. I created a model that included 5 dummy codes with weights of 1 for each of the hostile, kind, heat, cold, and neutral trials, respectively, and a weight of 0 for the nonsense-word trials. This effectively compared the “hostility” judgments for each individual trial type to the nonsense-word trial.

The dummy code for the hostile-word trials was positive and significant, $b = 0.64$, ($SE = 0.08$), $p < .001$; and the dummy code for the kind-word trials was negative and significant,

$b = -0.75$, ($SE = 0.09$), $p < .001$. Both the heat-word trials, $b = 0.10$, ($SE = 0.06$), $p = .13$, and cold-word trials, $b = 0.07$, ($SE = 0.06$), $p = .25$, were not significantly different from the nonsense trials. Also the comparison of the neutral trials and nonsense trials was significant, $b = -0.35$, ($SE = 0.07$), $p < .001$, which indicates these trials unexpectedly differed. The exploratory analyses suggest that any effects of the heat-word trials was driven by a difference with the neutral-word trials and not the nonsense trials.

Registered Report Testing the Heat-Aggression Association

A close replication of the pilot study was submitted as a Registered Report. There were two primary motivations behind this Registered Report. First, the pilot study was included towards the end of a larger data collection effort. Although there were no between-participants manipulations that preceded the Misattribution Task in the pilot study, it is difficult to know whether any of the preceding tasks affected the results of the pilot study. Similarly, there was a slight mishap with the data collection for the pilot study where one research assistant initially stopped data collection prior to the Misattribution Task. This mishap exclusively affected participants early in the data collection process. Therefore, the proposed study was a new sample replication that had the Misattribution Task be the only task in the study. Second, a close replication would provide information on the replicability of the effects obtained in the pilot study. Determining the replicability of the results from the pilot study was especially important given there were some unexpected results. For example, it was unexpected that the average judgments of “hostility” would differ between the neutral-word trials and the nonsense-word trials, it was unexpected that the cold-word trials would elicit higher judgments of “hostility” than the average of the neutral-word and nonsense-word trials, and it seemed the results were driven more by the the neutral-word trials eliciting judgments of non-aggressiveness more than the heat-word trials eliciting judgments of aggressiveness.

Modifications to the Study Methods

In addition to having the Misattribution Task be the sole focus of the study rather than being embedded within a larger study with several other tasks, there were two modifications to the methods of the current study. Both modifications were made in response to reviewers' comments during the Stage 1 review (i.e., prior to data collection). First, I doubled the number of trials in the Misattribution Task from 12 trials for each trial type and 72 trials overall to (6 words $\times$ 4 trials) 24 trials for each trial type and (24 trials for each trial type $\times$ 6 trial types) 144 trials overall. This modification was intended to increase the power of detecting differences between the trial types. Second, after completing the Misattribution Task and answering questions about speaking Chinese and knowing the meaning of the Chinese ideographs, participants responded to the single item "*Do you think your ratings of the Chinese symbols was influenced by the words that appeared before the Chinese symbols?*" using a scale with anchors *not at all*, *a little*, *sometimes*, *most of the time*, *almost all of the time*. Other than referring to words rather than faces, this item is the same as Bar-Anan and Nosek (2012) and Payne et al. (2013). I will refer to this item as the "perceived priming" item.

Planned Sample Size

I used the SIMR package (i.e., Bates et al., 2015) to conduct power analyses to detect the critical heat trial vs. comparison trials contrast coefficient. I estimated the power to detect an unstandardized coefficient of 0.15, which is approximately one-third of a standard deviation of a difference in the aggressiveness ratings based on the results of the pilot study. It was estimated that 134 participants were needed to achieve statistical power of 0.90. I excluded participants in the same way as in the pilot study, which meant that, assuming approximately 22% of participants will fail one of the manipulation checks, I needed to collect data from 164 participants to achieve a final sample of 134.

Participants

Participants were recruited from the Northern Illinois University community and were compensated \$5 for their participation. There were 167 individuals who participated in the study. Of these participants, 16 experienced an issue with the computer wherein the program was exited in the middle of the study. Of the remaining participants, 29 failed a manipulation check (i.e., they reported speaking Chinese or knowing the meaning of one or more Chinese ideographs, or they failed one of the Instructional Manipulation Check items) and were omitted from all analyses. This left a final sample of 122 participants. Although I achieved my target sample size, the number of participants in the final sample was slightly less than the goal of 134 participants.

In the final sample, 37 participants were male and 85 were female. The average age of participants in the final sample was 20.88 ($SD = 3.47$) years.

Results

Analytic Approach

The analyses proceeded in the same manner as the pilot study: A multi-level regression analysis was conducted with the 144 Misattribution Task trials nested within individual participants. Slopes and intercepts were allowed to randomly vary.

The first multi-level regression analyses used the same contrast coding scheme as the pilot study: Four contrast codes were created to separately compare the hostile-word trials, kind-word trials, heat-word trials, and cold-word trials to the average of the neutral and nonsense trials. Each contrast applied a weight of +0.667 to critical trial type, a weight of 0 to the non-critical trial types, and weights of -0.333 for the neutral and nonsense trials, respectively. A final contrast applied weights of 0, 0, 0, 0, +0.5, and -0.5 to the hostile, kind, hot, cold, neutral, and nonsense trials, respectively. A second multi-level regression analysis used the same dummy coding scheme as the exploratory analyses from the pilot study: Five dummy codes were created that individually compared each trial type (given a weight of 1)

to the nonsense trial type (given a weight of zero).

Next, an analysis was conducted that included participants' responses to the perceived priming item as a level 2 (i.e., person-level) predictor. This analysis was conducted such that a response of "not at all" was coded as zero. Thus, the coefficients in this model represent participants' Misattribution Task performance for participants who felt the words did not influence their Misattribution Task performance.

As an initial look at the "hostility" ratings for the different trial types, participants' average judgment of "aggressiveness" of the Chinese ideographs were computed separately for the hostile-word trials ($M = 2.93$, $SD = 0.48$), kind-word trials ($M = 2.03$, $SD = 0.55$), heat-word trials ($M = 2.66$, $SD = 0.39$), cold-word trials ($M = 2.60$, $SD = 0.40$), neutral-word trials ($M = 2.35$, $SD = 0.40$), and the nonsense-word trials ($M = 2.51$, $SD = 0.37$). These means are presented in Figure 2. The 95% confidence interval for the hostile-word trials, heat-word trials, and cold-word trials were all higher than the mid-point of the scale. The 95% confidence interval for the kind-word trials and the neutral trials were lower than the mid-point of the scale.

Testing the Heat-Aggression Association Hypothesis With Contrast Coding

Relative to the comparison trials, the average "hostility" hostility ratings were significantly higher for the hostile-word trials, $b = 0.62$, ($SE = 0.06$), $p < .001$; and were significantly lower for the kind-word trials, $b = -0.73$, ($SE = 0.07$), $p < .001$. Also, as in the pilot study, the contrast that compared the neutral-word trials and the non-sense word trials was unexpectedly significant, $b = -0.17$, ($SE = 0.04$), $p < .001$.

The contrast for heat-word trials was positive and significant, $b = 0.22$, ($SE = 0.04$), $p < .001$. Thus, the average "hostility" rating for the heat-word trials was 0.22 points higher than the average "hostility" ratings for the comparison trials, which is an effect that is consistent with the existence of a heat-aggression association. However, unexpectedly, the contrast for cold-word trials was also positive and significant, $b = 0.13$, ($SE = 0.04$), $p <$

.001.

Testing the Heat-Aggression Association Hypothesis With Dummy Coding

I next used a dummy coding scheme as another way of examining the results. This coding scheme effectively compared each individual trial (coded as 1) to the nonsense trials (coded as 0).

The dummy code for the hostile-word trials was positive and significant, $b = 0.41$, ($SE = 0.05$), $p < .001$; and the dummy code for the kind-word trials was negative and significant, $b = -0.48$, ($SE = 0.05$), $p < .001$.

The dummy code for the heat-word trials showed that the average “hostility” ratings for the heat-word trials was significantly greater than the nonsense trials, $b = 0.15$, ($SE = 0.04$), $p < .001$. This effect is both consistent with the results from the contrast coding and with the hypothesis that individuals hold a heat-aggression association. However, the ratings for the cold-word trials also were significantly greater than the nonsense trials, $b = 0.09$, ($SE = 0.04$), $p = .03$. This effect is seemingly inconsistent with the heat-aggression association hypothesis. Also the comparison of the neutral trials and nonsense trials was significant, $b = -0.17$, ($SE = 0.04$), $p < .001$.

Perceived Priming

After completing the Misattribution Task, participants responded to the item “*Do you think your ratings of the Chinese symbols was influenced by the words that appeared before the Chinese symbols?*” using a 0-4 scale with anchors *not at all*, *a little*, *sometimes*, *most of the time*, *almost all of the time*. Participants’ average response was 2.20 ($SD = 1.18$), which is between the responses “sometimes” and “most of the time.” There were 11 participants who reported their ratings were “not at all” influenced by the words in the Misattribution Task.

Participants’ response to the perceived priming item was included as a person-level moderator of their Misattribution Task performance. The same contrast coding scheme from

above was applied to these analyses. This model allowed me to test both for the main effect of the perceived priming item and whether the perceived priming item moderated any of the individual contrasts. Participants' response to the perceived priming item was not rescaled prior to the analysis; thus, the coefficients can be interpreted as the effects when participants reported their ratings were "not at all" influenced.

The main effect of the perceived priming item was not significant, $b = 0.02$, ($SE = 0.02$), $p = .39$. Further, as can be seen in Table 1, when the perceived priming item was zero (which was coded to correspond to a response of "not at all"), none of the contrast effects were significant. Also as can be seen in Table 1, as responses to the perceived priming items increased (indicating participants felt the words influenced their ratings), the effects for the individual trials got stronger. That is, as responses to the perceived priming items increased, the coefficients for hostile-word trials, heat-word trials, and cold-word trials got more positive, and the coefficient for the kind-word trials got more negative. This suggests that the effects of trial type only emerged for participants who reported their responses were influenced by the words during the Misattribution Task.

Discussion

DeWall and Bushman (2009) put forth evidence that individuals hold cognitive associations between the constructs of hot temperatures and aggression; however, subsequent research cast doubt on the replicability of those effects (e.g., McCarthy, 2014). Given the uncertainty about those effects, the current studies used methods that were believed to be favorable to detecting an effect that would be consistent with a heat-aggression association—i.e., a highly-repeated within-participants design with a short delay between the heat-related stimuli and the outcome variable. Despite these favorable conditions for detecting an effect, there was mixed evidence in support of the heat-aggression association hypothesis.

In favor of the existence of a heat-aggression association, ambiguous stimuli were

judged as more hostile when briefly preceded by heat-related words relative to trials preceded by neutral words and nonsense words. This effect was found in both the pilot study and the Registered Report. These results are consistent with the idea that exposure to heat-related words briefly caused a temporary increase in the accessibility of aggressive cognitions, which, in turn, caused the interpretation of ambiguous stimuli to be more hostile. Thus, the current results provide a conceptual replication of the *hypothesis* tested by DeWall and Bushman (2009). However, it is important to keep in mind that although the current results are consistent with the hypothesis that exposure to heat-related stimuli causes a subsequent increase in aggressive cognitions, the current results should not be taken as evidence that the *methods* used by DeWall and Bushman would reliably produce an effect that is practically and routinely detected. Until the methods used by DeWall and Bushman can be shown to produce replicable effects, researchers should be hesitant to believe that the exposure to heat-related stimuli has anything beyond a brief influence on a relatively simple perceptual task. Likewise, future research can test whether the current effects are independently replicable and to test whether the current effects are meaningfully related to the cognitive processes that actually contribute to aggressive behaviors.

Nevertheless, not all of the effects were supportive of the existence of a heat-aggression association. Notably, the cold-word trials also produced higher “hostility” judgments than the comparison trials in both the pilot study and the Registered Report. Although DeWall and Bushman (2009) did not explicitly state a hypothesis about stimuli related to cold temperatures, it is clearly implied that the lack of an effect for their “cold priming” condition was considered consistent with their hypothesis that exposure to heat-related stimuli specifically would cause an increase in aggressive cognitions. Thus, because both heat-word trials and cold-word trials both caused a subsequent increase in “hostility” judgments in the Misattribution Task, the current overall pattern of results could be considered both inconsistent with the overall pattern of results reported by DeWall and Bushman (2009) and with the notion that individuals associate hot temperatures, but not cold temperatures, with

aggression. The current results suggest several possibilities other than a heat-aggression association. For example, individuals may hold separate heat-aggression associations and cold-aggression associations, individuals may hold a generic temperature-aggression association, individuals may hold an “aversive stimulus”-aggression association (in which both hot temperatures and cold temperatures are considered aversive), etc. Unfortunately, the current results could not disambiguate these speculations. Future research can try to more fully examine whether this cold temperature-aggression effect is damning to the notion that individuals hold cognitive associations between hot temperatures and aggression.

Also inconsistent with the notion that the current results are due to the expression of a cognitive heat-priming *association* is that the perceived priming item moderated participants’ Misattribution Task performance. Specifically, participants who reported that the words did not affect their Misattribution Task performance did not, in fact, show any differences in their judgments for any trials. Conversely, participants who reported that the words did affect their Misattribution Task performance were the ones who judged the ambiguous stimuli differently. Thus, participants seem to have introspective access to the cognitive processes that affected their Misattribution Task performance and accurately responded to the perceived priming item. Notably, this finding does not change the fact that there was clearly empirical effects that were detected in the Misattribution Task; however, this finding should affect *why* we believe this effect was detected. It seems that the current findings do not operate through a cognitive process that is introspectively inaccessible. And it is possible that participants’ Misattribution Task performance was driven by participants controlled cognitive processes (e.g., they consciously recognize the word and rate the ambiguous stimuli accordingly).

In addition to the critical heat-word trials, the current study also included hostile-word trials and kind-word trials, which were included as “positive controls.” These positive control trials are important for two reasons. First, the positive controls demonstrated that the conditions to observe theory-consistent results were realized. Relative to the comparison

trials, participants rated the Chinese ideographs as more hostile when preceded by hostile words and as less hostile when preceded by kind words. Because the effect for the heat-word trials was in the same direction as the hostile-word trials and in the opposite direction as the kind-word trials, this pattern of results adds credence to the interpretation that the effect for the heat-word trials was due to individuals associating heat-related stimuli with aggression. Second, the magnitude of the effects for the positive control trials provides a useful comparison to interpret the effects for the heat-word trials. In this respect, the magnitude of the effects for the heat-word trials was about one-third the magnitude for the hostile-word trials. Because heat-related stimuli are semantically more remotely related to the concept of “hostility” than hostile-related stimuli, it is logical that effects for the heat-word trials were smaller than the hostile-word trials.

In summary, the current results found evidence that exposure to heat-related stimuli caused a brief influence on subsequent judgments of hostility. Although this finding supports the hypothesis that individuals hold a cognitive association between hot temperatures and aggression, other results found a similar effect for cold-related stimuli and that these results are possibly driven by controlled cognitive processes.

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Table 1

Multi-Level Regression Results of Misattribution Task With Perceived Priming as a Moderator

	Estimate	SE	df	t	p
(intercept)	2.48	0.04	122.00	55.78	<.001
hostile-word contrast	-0.07	0.11	122.00	-0.63	.527
kind-word contrast	0.14	0.12	122.00	1.13	.262
heat-word contrast	0.03	0.08	122.00	0.40	.689
cold-word contrast	-0.15	0.08	122.00	-1.90	.059
neutral vs. nonsense contrast	0.01	0.08	122.00	0.17	.869
perceived priming	0.02	0.02	122.00	0.86	.393
Perceived Priming x Hostile-Word Contrast	0.31	0.05	122.00	6.97	<.001
Perceived Priming x Kind-Word Contrast	-0.39	0.05	122.00	-8.05	<.001
Perceived Priming x Heat-Word Contrast	0.09	0.03	122.00	2.79	.006
Perceived Priming x Cold-Word Contrast	0.13	0.03	122.00	4.12	<.001
Perceived Priming x Neutral vs. nonsense Contrast	-0.08	0.03	122.00	-2.57	.011

Note. Multi-level regression testing whether participants' Misattribution Task performance was moderated by their response to the perceived priming item. Estimates are the coefficients using the contrast coding scheme.

Figure 1. Each individual data point represents an individual's average "hostility" rating of 12 Chinese ideographs for each trial type. The errorbars represent 95% confidence intervals for each trial type (i.e., the confidence intervals are not adjusted for the correlations between the data points).

Figure 2. Each individual data point represents an individual's average "hostility" rating of 24 Chinese ideographs for each trial type. The errorbars represent 95% confidence intervals for each trial type (i.e., the confidence intervals are not adjusted for the correlations between the data points).