Aftereffects of self-control on positive emotional reactivity

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Abstract

According to the process model of ego depletion, exercising self-control causes shifts in motivation and attention that may increase positive emotional reactivity. In an initial study and a preregistered replication, participants exercised self-control (or not) on a writing task before reporting their emotional responses to positive, negative, and neutral images. In Study 1 ($N = 256$) we found that exercising (versus not exercising) self-control increased positive emotional responses to positive images among more extraverted individuals. In Study 2 ($N = 301$) we found that exercising self-control increased positive reactivity independent of extraversion. These findings support the process model of ego depletion and suggest that exercising self-control may influence responding that does not entail self-control (i.e., positive emotional reactivity)—an outcome that is not anticipated by the limited resource model of self-control.

Key words: ego depletion, emotion, limited resources, process model, self-control

Aftereffects of self-control on positive emotional reactivity

Good self-control contributes to several desirable long-term outcomes, including mental and physical health, financial well-being, and academic and professional achievement (Vohs & Baumeister, 2011). But acts of self-control may also carry short-term costs. Numerous experiments have found that overriding or altering one's predominant response tendencies temporarily reduces success at subsequent attempts at self-control. The leading explanation for this behavioral pattern, known as the *ego depletion effect*, is that exercising self-control at Time 1 consumes and depletes a limited inner resource needed to succeed at self-control at Time 2 (Muraven & Baumeister, 2000).

The ego depletion effect may also be explained without reference to limited resources. According to the process model of ego depletion, exercising self-control is an aversive event that causes shifts in motivation and attention away from self-control and toward more appealing activities (Inzlicht & Schmeichel, 2012; Inzlicht, Schmeichel, & Macrae, 2014).¹ These shifts may be particularly consequential when pleasurable stimuli are present in the environment following a self-control attempt. In this view, ego depletion is essentially a manifestation of emotion regulation: After engaging in frustrating or otherwise unpleasant attempts to override or alter a response, individuals become more attuned to opportunities to improve their emotional state.

The ego depletion effect has recently received intense scrutiny and skepticism (for an overview, see Frieze, Loschelder, Gieseler, Frankenbach, & Inzlicht, 2018). Briefly, a preregistered study conducted across multiple laboratories found null results of exercising self-

¹ We refer to this model as the process model of ego depletion to be consistent with the terminology used by the original authors of the model, even though no depletion is assumed to occur (i.e., the model does not assume the existence of a limited resource).

control at Time 1 on self-control at Time 2 (Hagger et al., 2016; cf. Baumeister & Vohs, 2016a), other preregistered studies have observed significant but smaller-than-expected effects (Dang, Liu, Liu, & Mao, 2017; Garrison, Finley, & Schmeichel, in press), and one meta-analytic estimate suggested that the magnitude of the ego depletion effect is not appreciably different from zero (Carter, Kofler, Forster, & McCullough, 2015; cf. Cunningham & Baumeister, 2016; Dang, 2018; Inzlicht, Gervais, Berkman, 2015; Simonsohn, 2017). These developments have cast doubt on the reliability of the ego depletion effect.

Even if exercising self-control at Time 1 does not deplete a limited resource and therefore undermine self-control at Time 2, as skeptics have suggested, exercising self-control may nonetheless influence other processes and responses. Perhaps some of the inconsistent effects observed in past research stem from an exclusive focus on self-control-related dependent measures suggested by the limited resource model. Such measures may not adequately capture the aftereffects of exercising self-control.

The current studies differ from past research by focusing on the aftereffects of self-control on uncontrolled responding. Specifically, the current studies tested the hypothesis that exercising self-control at Time 1 increases positive emotional reactivity at Time 2. This hypothesis can be derived from the process model of ego depletion but not the resource model, as described below.

Aftereffects of self-control on positive reactivity

One main implication of the resource model is that all acts of self-control rely on the same underlying capacity, so that exercising self-control at Time 1 undermines success at even quite different self-control challenges at Time 2 (Muraven & Baumeister, 2000). But what if no

self-control is required at Time 2? Does prior self-control influence subsequent uncontrolled responding?

The resource model does not supply answers to these questions because the hypothesized resource pertains only to self-control. Hence, exerting self-control at Time 1 is irrelevant for most Time 2 responses or behaviors insofar as they stem from habits, routines, or other more automatic processes that do not entail self-control. For example, the emotions that arise while viewing and responding to emotional pictures (as in the current experiments) should be unaffected by the prior depletion of limited resources because passive picture viewing requires no self-control. Viewing positive emotional pictures, in particular, does not typically require one to override a response and thus should not be influenced by the state of the limited resource for self-control.

The process model, by contrast, suggests that exercising self-control at Time 1 may influence responding that does not entail self-control at Time 2. Specifically, this model proposes that exercising self-control is an aversive, unpleasant activity that biases motivation and attention toward more rewarding or appealing activities. If the process model is correct, then exercising self-control at Time 1 may increase the subjective emotional impact of viewing positive pictures at Time 2, as individuals become more attuned to positive stimuli and positive feelings after an effortful bout of self-control.

Several past findings are consistent with the process model view. For example, participants in one study completed either a simple math task or an effortful thought suppression task at Time 1, and then attempted to inhibit smiles and other signs of amusement while watching humorous video clips at Time 2 (Muraven, Tice, & Baumeister, 1998, Study 3). Participants who had suppressed their thoughts went on to smile more and express more positive

emotion while watching the amusing videos. In another study, chronic dieters who suppressed their emotional expressions during a movie at Time 1 consumed more ice cream on a taste-and-rate task at Time 2, compared to dieters who did not suppress their emotional expressions at Time 1 (Vohs & Heatherton, 2000). These findings are consistent with the idea that individuals respond more favorably to positive events after exercising self-control on an unrelated task.

But the findings reviewed above suffer from an interpretational ambiguity. Did exercising self-control increase positive emotional expressions (Muraven et al., 1998) or ice cream intake (Vohs & Heatherton, 2000) because of an increase in positive emotional reactivity, as the process model would predict? Or because participants were temporarily less capable of suppressing their smiles or sticking to their diets, as the resource model would predict? The observed outcomes—smiles and ice cream consumption—are not sufficient to distinguish between the two predictions because both positive reactivity and poor self-control could contribute to each outcome.

A more recent study found evidence to support the process model account. Participants completed a self-control task (or not) prior to viewing a mixture of neutral and emotional images (Schmeichel, Crowell, & Harmon-Jones, 2016). Crucially, unlike previous studies (e.g., Muraven et al., 1998), participants were not instructed to suppress their emotional responses at Time 2.

Rather, they were instructed simply to view the images and respond in whatever way was normal and natural for them, thereby removing the requirement to exert control.

Electroencephalographic activity revealed that exercising self-control at Time 1 caused an increase in relative left frontal cortical activity during emotional (both positive and negative) picture viewing at Time 2, but only among individuals higher in trait approach motivation.

Greater relative left frontal cortical activity is thought to reflect relatively greater approach motivation (Coan & Allen, 2003; Kelley, Hortensius, Schutter, & Harmon-Jones, 2017; Harmon-

Jones & Gable, 2018), so the results from this study suggested that exercising self-control shifts motivation during emotional images among approach-prone persons. This finding is not readily explained by the resource model; participants were not trying to exercise self-control at Time 2, so the state of the resource for self-control was irrelevant. But that study focused on neural measures and did not assess emotional experience, so the effects of exercising self-control on subjective responding remain unknown. Do individuals experience more positive emotions in response to pleasant events after they have exercised self-control?

Aftereffects of self-control on negative reactivity

Although the resource model does not predict changes in positive reactivity, it could be used to derive a hypothesis about the aftereffects of self-control on negative emotional reactivity. If one assumes that individuals spontaneously (i.e., without being instructed) down-regulate their responses to negative stimuli (e.g., Pu, Schmeichel, & Demaree, 2010), perhaps out of a desire to appear undisturbed or to maintain a more positive emotional state, then exercising self-control at Time 1 may undermine the success of these emotion regulation efforts and thereby increase negative reactivity at Time 2. Evidence of increased reactivity to negative images may thus support the idea that prior efforts at self-control undermine spontaneous attempts to down-regulate negative emotion. Such a pattern would be broadly consistent with the limited resource model.

Like the resource model, the process model also does not make specific predictions regarding negative reactivity. But insofar as exercising self-control motivates shifts toward reward and good feelings, it is plausible that exercising self-control also increases the tendency to avoid or ignore aversive events. Put differently, any increase in positive reactivity after exercising self-control may be accompanied by a corresponding decrease in negative reactivity.

Therefore, the process model could be interpreted to predict that exercising self-control at Time 1 reduces negative emotional reactivity at Time 2. One previous study found suggestive evidence in this regard, insofar as exercising self-control increased a neural indicator of approach motivation in response to negative images (i.e., relative left frontal asymmetry; Schmeichel et al., 2016), but this result had not been predicted and has yet to be replicated. In the case of negative emotional reactivity, then, the resource model and the process model suggest divergent predictions, but these predictions require additional assumptions not inherent in either model.

Extraversion and Neuroticism as Potential Moderators

The foregoing predictions regarding emotional reactivity assume that all persons respond similarly to emotional stimuli. But past research has suggested that individual differences in extraversion and neuroticism moderate reactivity to emotional events. Gray (1981) and others (e.g., Costa & McCrae, 1980) hypothesized links between extraversion and sensitivity to positive stimuli and between neuroticism to sensitivity to negative stimuli, respectively. Most relevant for present purposes is evidence that more extraverted persons may report more positive reactions to positive stimuli, whereas more neurotic persons may report more negative reactions to negative stimuli (e.g., Gross, Sutton, & Ketelaar, 1998; Larsen & Ketelaar, 1989, 1991; see also Letzring & Adamcik, 2015; Lucas & Baird, 2004).

Based on evidence that extraversion and neuroticism are associated with emotional states (e.g., Rusting & Larsen, 1997) and may moderate reactivity to emotional stimuli (e.g., Larsen & Ketelaar, 1989), we hypothesized that these traits may influence the effects of Time 1 self-control on Time 2 emotional reactivity. We expected that picture valence (positive, negative, or neutral) would explain most of the variance in emotional reactivity. However, we reasoned that any effect of prior self-control on positive emotional reactivity would be most prevalent among

individuals prone to experience positive emotion (i.e., those higher in extraversion), whereas any effects on negative emotional reactivity would be most prevalent among individuals prone to experience negative emotion (i.e., those higher in neuroticism).

To test these hypotheses, we conducted an experiment in which we measured trait extraversion and neuroticism, manipulated the exercise of self-control at Time 1, and assessed emotional reactivity to negative, neutral, and positive images at Time 2. We then conducted a preregistered direct replication in Study 2. Before reporting those experiments, we first report the results of a pilot study testing the manipulation of Time 1 self-control.

Pilot Study

According to the process model of ego depletion, aftereffects of self-control may stem in part from the aversive feelings that attend efforts to override or alter a predominant response tendency. We therefore conducted a pilot study to verify that the self-control manipulation participants completed in the primary experiments—a writing task that either did or did not require the exercise of self-control—was successful in eliciting aversive feelings and feelings of effort.

Method

Participants and Design

Seventy undergraduate students (66 women, 14 men) participated in exchange for extra credit points in a psychology course. All participants completed a free writing task and a controlled writing task in a within-subjects design. Immediately after completing each task, participants reported on their subjective experiences during the task. A sample of $N = 70$ provided 80% power to detect a medium-sized effect of the writing manipulation.

Materials and Procedures

Participants sat at desks in a large lecture hall. After providing informed consent, participants wrote two short stories as follows.

Writing Task. Participants spent six minutes completing the *controlled writing task*. Participants were instructed to write about a recent trip they had taken. They were told the story could be about a trip to the store, a trip to another country, or some other trip of their choosing. Participants then received additional instructions: “Very important! Do not use the letters A or N anywhere in your story! If you find yourself writing a word that includes the letters A or N, please stop writing that word and find an alternate way to express your thoughts.”

After writing for six minutes, participants were prompted to list the one word that best described how they felt during the writing task. Then they rated how much mental effort and how much frustration they experienced during the task using scales from 1 (*none*) to 7 (*very much*).

All participants then proceeded to complete the *free writing task*. This time, participants were encouraged to write about a recent trip and no restrictions were placed on their letter use. After writing for six minutes, participants listed the one word that best described how they felt during this version of the writing task and rated how much mental effort and frustration they experienced. Previous research has observed that the controlled writing task induces ego depletion (e.g., Schmeichel, 2007). All data are available online (<https://osf.io/q74tx/>).

Results

As expected, the controlled writing task was rated as more effortful ($M = 6.21$, $SD = 0.99$) than the free writing task ($M = 2.14$, $SD = 1.12$), $t(69) = 21.44$, $p < .001$, 95% CI [4.22, 4.92], $d = 2.57$. The controlled writing task was also rated as more frustrating ($M = 5.84$, $SD =$

1.36) than the free writing task ($M = 1.27$, $SD = 0.54$), $t(69) = 25.84$, $p < .001$, 95% CI [3.69, 4.45], $d = 3.35$. The three most frequently used words to describe the experience of the controlled writing task were: *frustrated* (27.1%); *stressed* (10.0%); and *limited* and *challenged* (both 4.3%). The three most frequently used words to describe the experience of the free writing task were: *nostalgic* (11.4%); *calm*, *easy*, *free*, and *relaxed* (all 8.6%); and *fine* and *relaxing* (both 4.3%).

Discussion

The results of the pilot study confirmed that the controlled writing task requires more effort and invokes greater frustration compared to the free writing task. This evidence supports the idea that the controlled writing task entails more self-control. Furthermore, the descriptive analysis of the most frequently used words to describe the tasks revealed very different subjective experiences—the controlled writing task was more frustrating than the more benign free writing task. These findings are consistent with past evidence that self-control manipulations tend to be subjectively aversive and effortful (see Hagger et al., 2010).

Study 1

To test the aftereffects of self-control on emotional responding, we conducted an experiment in which we measured trait extraversion and neuroticism, manipulated the exercise of self-control at Time 1 using the writing task from the pilot study, and assessed emotional reactivity to negative, neutral, and positive images at Time 2.

Method

Participants were randomly assigned to condition in a 2 (Writing Condition: controlled writing vs. free writing) $\times$ 3 (Image Type: positive, neutral, or negative images) mixed-factorial design, with picture type as a within-subjects variable.

Participants

Two hundred fifty-six undergraduate students (153 women; age $M = 18.73$, $SD = 0.99$) participated in exchange for credit toward a course requirement, providing us 80% power to detect a small-to-medium sized effect ($d = 0.35$) of the writing manipulation. We based our sample size on the power to detect a small-to-medium sized effect, which splits the difference between meta-analytic estimates of the ego depletion effect (see Carter, Kofler, Forster, & McCullough, 2015; Hagger, Wood, Stiff, & Chatzisarantis, 2010). Participants were randomly assigned between the free writing ($n = 130$) and controlled writing ($n = 126$) conditions. Sixteen additional participants were excluded from analyses: 5 had missing data (3 due to computer error and 2 due to experimenter error), and 11 failed to follow the writing task instructions (e.g., drew pictures, did not write for the full five minutes, or used an inordinate number of *as* and *ns* on the controlled writing task; see below).

Materials and Procedures

Participants arrived individually for a laboratory-based experiment on personality and emotion. After providing informed consent, participants completed the Big Five questionnaire (Goldberg, 1992), from which we derived scores from the 10-item extraversion ($M = 31.78$, $SD = 8.17$, $\alpha = .90$) and neuroticism ($M = 30.12$, $SD = 6.83$, $\alpha = .82$) subscales. Sample items on the extraversion subscale include “I am the life of the party,” and “I am quiet around strangers” (reversed coded). Sample items on the neuroticism subscale include “I get upset easily” and “I seldom feel blue” (reversed coded). Participants responded to all items using a scale from 1 (*very inaccurate*) to 5 (*very accurate*).

Self-control manipulation. Next, participants spent six minutes writing a short story under one of the two sets of instructions described in the pilot study. Specifically, participants in

the *free writing condition* were instructed to write about a recent trip. Participants in the *controlled writing condition* received the additional instruction: “Very important! Do not use the letters A or N anywhere in your story! If you find yourself writing a word that includes the letters A or N, please stop writing that word and find an alternate way to express your thoughts.” Hence, participants in the latter group inhibited the use of two common letters, whereas those in the former group wrote without restrictions.

Emotional image-viewing task. Participants then viewed 29 IAPS images (9 positive, 10 negative, 10 neutral; Lang, Bradley, & Cuthbert, 2005) presented in a random order. We selected positive images depicting appetitive objects or activities that elicit high (positive) valence and arousal, negative images that depicted aversive or threatening objects or events that elicit low (negative) valence and high arousal, and neutral images that elicit middling (neutral) valence and low arousal.² Images remained onscreen until participants reported their emotional responses using self-assessment manikins (SAM; Bradley & Lang, 1994) for valence from 1 (*unhappy*) to 7 (*happy*) and arousal from 1 (*calm*) to 7 (*excited*). Participants also rated how much the content of each image elicited empathy and concern, both from 1 (*none*) to 7 (*quite a bit*). After the image-viewing task, participants indicated how much they tried to increase/decrease their emotional

² According to published norms (Lang et al., 2005), the positive images (IAPS numbers: 4608, 4658, 4695, 7200, 7260, 7350, 7390, 8161, 8186) have an average valence rating of $M = 7.00$ ($SD = 0.29$) and an average arousal rating of $M = 5.78$ ($SD = 0.84$); negative images (IAPS numbers: 1205, 1270, 3130, 3250, 3400, 3550, 6230, 6550, 6560, 7380) valence $M = 2.73$ ($SD = 0.70$) and arousal $M = 6.35$ ($SD = 0.74$); and neutral images (IAPS numbers: 2393, 2397, 2506, 2516, 2850, 5534, 7025, 7035, 7053, 7182) valence $M = 5.05$ ($SD = 0.27$) and arousal $M = 3.12$ ($SD = 0.41$). One less positive image was presented to participants than other image types due to a programming error. We selected images within each image category that contained roughly equal proportions of human and non-human content (5 of 9 positive, 5 of 10 negative, and 5 of 10 neutral images contained humans).

responses to positive/negative images, all from 1 (*none*) to 7 (*quite a bit*), and to describe what, if anything, they did to change their emotions.

Individual differences measures. Last, participants completed the following questionnaires included for exploratory purposes: emotion regulation questionnaire (Gross & John, 2003), brief self-control scale (Tangney, Baumeister & Boone, 2004), Toronto empathy questionnaire (Spreng, McKinno, Mar, & Levine, 2009), and a general demographic form. Results pertaining to the brief self-control scale and self-reported emotion regulation efforts as a function of writing condition, extraversion, and neuroticism are reported in the Supplemental Materials (<https://osf.io/7gt8z/>). All data are available online (<https://osf.io/n5p2m/>).

Results

Data analyses proceeded as follows. First, we assessed the effects of sex of participant on emotion responses (valence and arousal) in light of previous evidence for sex differences in emotional responding to IAPS images (e.g., Bradley, Codispoti, Sabatinelli, & Lang, 2001). Second, we used multilevel modeling (MLM) to examine emotional responses as a function of image type and writing condition, taking trait extraversion and neuroticism into account. Table 1 displays descriptive statistics and correlations within each writing condition for the variables used in the analyses.

In the MLMs, responses to each image, nested within type (neutral, negative, and positive), nested within participants, served as the outcome, with separate models for valence and arousal responses. Image type was a level 1 predictor (i.e., direct predictor of valence or arousal). Writing condition, gender, and personality traits served as level 2 predictors of the intercept and image type effects. The models included random intercepts (to account for dependence of ratings within participants) and random slopes (to examine cross-level interactions between personality

traits and image valence). Extraversion and neuroticism were mean-centered, and writing condition, image type, and gender were effect-coded.

Models were fit in MPlus version 8 (Muthen & Muthen, 2017) using full information maximum likelihood estimation with robust standard error estimation (all other analyses calculated using SPSS).³ All random effects were allowed to covary. We used pseudo R^2 (Snijders & Bosker, 1999) to quantify the predictive power of the models and semi-partial R^2 to assess the contributions of individual predictors (Edwards, Muller, Wolfinger, Qaqish, & Schabenberger, 2008). The statistical significance of the image type variable was assessed using likelihood ratio tests of nested models in which we compared a model with freely estimated regression coefficients for each effect-coded image type variable to a model in which the coefficients for the two image type effect-coded variables were fixed to zero (see West, Aiken, & Krull, 1996; Yuan & Bentler, 2000). The likelihood ratio tests yield a χ^2 statistic, which was translated to an F -statistic for interpretive ease. MPlus syntax for the MLMs is available in the Supplemental Materials (<https://osf.io/7gt8z/>).

Valence and arousal by participant sex. Women reported more negative emotional responses to negative images ($M = 1.91$, $SD = 0.85$) than did men ($M = 2.21$, $SD = 0.74$), $t(254) = 2.97$, $p = .003$, 95% CI [0.10, 0.51], $d = 0.38$. Women also reported more positive emotional responses to positive images ($M = 5.15$, $SD = 0.73$) than did men ($M = 5.37$, $SD = 0.75$), $t(254) = 2.31$, $p = .021$, 95% CI [0.03, 0.40], $d = 0.30$. Men and women did not differ in self-reported arousal in response to negative images, $p = .348$, or positive images, $p = .486$. Because of the

³ Analyses for Study 1 were originally completed in SPSS, as reported in the preregistration for Study 2. MPlus is a more powerful and flexible program for modeling random effects and offers more robust methods of modeling, so we report the MPlus analyses for both Study 1 and Study 2. The findings do not differ between the MPlus and SPSS analyses.

observed sex differences in valence and prior research (e.g., Bradley et al., 2001), we included participant sex as a covariate in the analyses of emotional responding. Omitting sex as a covariate did not change the significance levels reported below.

Valence. Overall, the model explained roughly half of the variance in self-reported valence at the level of image type, $pseudo R^2_{Level 1} = .54$, and a modest amount at the level of the individual participant, $pseudo R^2_{Level 2} = .08$ (Cohen, 1992; Edwards et al., 2008). We observed significant main effects of image type, $F(2, 250) = 116.53, p < .001, R^2_{\beta} = 0.482$, and neuroticism, $F(1, 250) = 5.929, p = .015, R^2_{\beta} = 0.023$, which were qualified by a two-way Writing Condition $\times$ Neuroticism interaction, $F(1, 250) = 5.07, p = .024, R^2_{\beta} = 0.020$, and a cross-level three-way Image Type $\times$ Writing Condition $\times$ Extraversion interaction, $F(2, 250) = 4.02, p = .018, R^2_{\beta} = 0.031$. See Table 2.⁴

Probing the Writing Condition $\times$ Neuroticism interaction revealed that neuroticism predicted lower (more negative) valence responses in the free writing condition, $B = -0.019, SE(B) = 0.006, p = .001$, but not in the controlled writing condition, $B = -.001, SE(B) = 0.006, p = .864$. We also explored the interaction by testing the effect of writing condition on valence responses at high (+1 *SD*) and low (-1 *SD*) levels of neuroticism. Writing condition influenced valence at high neuroticism, $B = 0.183, SE(B) = 0.079, p = .020$, but not at low neuroticism, $B = -0.069, SE(B) = 0.079, p = .364$, such that individuals higher in neuroticism reported higher (i.e., more positive) valence across all image types in the controlled writing condition.

⁴ Because image type was a categorical variable with three levels, image type was entered into the model as two separate effect-coded variables. The results in Table 2 thus do not directly report the single overall effect of image type. Instead, the table reports the results associated with the two separate effect-coded variables. The effects of image type and associated interactions reported in the main text were calculated using likelihood ratio tests of nested models (see West, Aiken, & Krull, 1996).

Probing the three-way Image Type $\times$ Writing Condition $\times$ Extraversion interaction separately within each image type (Aiken & West, 1991; Preacher, Curran, & Bauer, 2006) revealed that extraversion predicted more positive valence in response to positive images in the controlled writing condition, $B = 0.026$, $SE(B) = 0.008$, $p = .001$, but not in the free writing condition, $B = 0.000$, $SE(B) = 0.007$, $p = 0.999$. See Figure 1. Extraversion did not interact with writing condition to predict valence in response to negative images, $ps > 0.300$, or neutral images, $ps > 0.055$.

We also probed the three-way interaction by testing the effect of writing condition on valence responses to positive images at high (+1 *SD*) and low (-1 *SD*) levels of extraversion. The effect of writing condition was significant at high extraversion, $B = 0.283$, $SE(B) = 0.116$, $p = .015$, but not at low extraversion, $B = -0.149$, $SE(B) = 0.137$, $p = .279$. Neyman-Johnson regions of significance revealed that the effect of controlled writing on positive reactivity was significant among individuals 0.67 standard deviations or more above the mean extraversion score. Thus, performing the controlled writing task increased subsequent valence responses to positive images among individuals higher in extraversion.

Arousal. Overall, the two-level model explained a large portion of the variance in self-reported arousal at the level of image type, $pseudo R^2_{Level 1} = .40$ and a small amount of variation at the level of the individual participant, $pseudo R^2_{Level 2} = .05$ (Cohen, 1992; Edwards et al., 2008). The MLM for arousal responses revealed main effects of image type, $F(2, 250) = 174.53$, $p < .001$, $R^2_{\beta} = 0.583$, and extraversion, $F(1, 250) = 5.770$, $p = .016$, $R^2_{\beta} = 0.023$, such that positive and negative images elicited more arousal than neutral images, and more extraverted participants reported higher arousal regardless of image type. All other effects were non-significant. See Table 2.

Discussion

Study 1 yielded evidence that exercising self-control at Time 1 influences emotional reactivity at Time 2. Specifically, we found that exercising self-control increases subsequent emotional reactivity to positive images, but only among individuals higher in extraversion. Among individuals lower in extraversion, exercising self-control did not influence positive emotional reactivity. We also observed an unexpected result, whereby exercising self-control reduced the association between neuroticism and emotional reactivity across all image types. Exercising self-control did not influence self-reported arousal in response to the images.

These results lend support to the process model, which proposes that exercising self-control causes a shift in motivation and attention toward positive or rewarding events. The resource model does not predict this finding. Further, the results provided little evidence that exercising self-control at Time 1 undermines spontaneous efforts to down-regulate negative emotions at Time 2, as the resource model might predict. Emotional responding to negative images was largely unaffected by the manipulation of prior self-control. We also observed, unexpectedly, that exercising self-control at Time 1 reduced the association between neuroticism and valence (across all image types) at Time 2.

The increased positive reactivity we observed among participants who had previously exercised self-control depended on individual differences in extraversion. We had expected to find a main effect of prior self-control on positive emotional reactivity, as implied by the process model, but only more extraverted individuals showed the increase. This pattern is in line with past research suggesting that the propensity to experience positive emotion may moderate the aftereffects of self-control. For example, a study by Crowell, Kelley, and Schmeichel (2014) found that exercising self-control increases approach-oriented responding especially among

individuals higher in trait approach motivation. They reasoned that, insofar as exercising self-control shifts attention and motivation toward more rewarding events, more approach-oriented individuals should be more likely to show the effect. A similar pattern appears to have emerged in Study 1, such that exercising self-control increased positive emotional reactivity especially among more extraverted individuals (who are prone to experience positive affect and tend to be more approach-oriented; e.g., Lucas & Baird, 2004). The implication is that the aftereffects of self-control vary across individuals, particularly as a function of traits pertaining to reward sensitivity or positive affectivity.

Study 2

To test the robustness of the positive reactivity findings from Study 1 and to see if the unexpected finding regarding neuroticism would replicate, we conducted a preregistered direct replication in Study 2 (<https://osf.io/rmgz4/>). Specifically, we preregistered the primary prediction that extraversion and writing condition would interact to influence responses to positive images, such that extraversion relates to more positive valence responses to positive images in the controlled writing condition relative to the free writing condition (as in Study 1). Additionally, we preregistered the secondary prediction that neuroticism and writing condition would interact to influence valence in response to all images as found (unexpectedly) in Study 1. We also predicted gender differences, whereby women would rate images more negatively relative to men as in Study 1, thereby providing additional justification for including gender as a covariate in our analyses.

Method

All methods and materials were identical to Study 1.

Participants

We preregistered our intent to collect usable data from at least 300 participants, which would yield a larger sample size than Study 1. Three hundred and one undergraduate students (195 women; age $M = 18.88$, $SD = 1.15$) completed the experiment in exchange for credit toward a course requirement. Participants were randomly assigned between the free writing ($n = 158$) and controlled writing ($n = 143$) conditions. Nineteen additional participants were excluded from analyses: 4 had missing data due to computer error, 2 reported participating in a similar study before, 1 decided to stop before finishing the image viewing task, and 13 failed to follow instructions as specified by our preregistered exclusion criteria (e.g., failed to alert experimenter at appropriate time and completed emotion task before writing task, left blanks where *as* and *ns* should have been instead of choosing different words, used an inordinate number of *as* and *ns* on the controlled writing task).

Materials and Procedures

We again used the Big Five questionnaire (Goldberg, 1992) to derive scores from the 10-item measures of extraversion ($M = 31.68$, $SD = 7.97$, $\alpha = .903$) and neuroticism ($M = 29.27$, $SD = 7.24$, $\alpha = .837$). Once again, results pertaining to the brief self-control scale and self-reported emotion regulation efforts as a function of writing condition, extraversion, and neuroticism are reported in the Supplemental Materials (<https://osf.io/7gt8z/>). All data are available online (<https://osf.io/pgrzs/>).

Results

Data analyses were identical to Study 1 and preregistered online (<https://osf.io/rmgz4/>). Table 3 displays descriptive statistics and correlations within each writing condition for the variables included in the analyses.

Valence and arousal by participant sex. Women reported more negative emotional responses to negative images ($M = 1.85$, $SD = 0.78$) than did men ($M = 2.39$, $SD = 0.80$), $t(298) = 5.69$, $p < .001$, 95% CI [0.35, 0.37], $d = 0.68$, and women reported higher arousal responses to negative images ($M = 4.64$, $SD = 1.33$) than did men ($M = 4.25$, $SD = 1.31$), $t(298) = 2.41$, $p = .017$, 95% CI [0.07, 0.70], $d = 0.30$. Men and women did not differ in valence or arousal in responses to positive images, $ps > .200$. Because of the observed differences and our a priori intention to replicate the analyses used in Study 1, we included participant sex as a covariate in the analyses of emotional responding. Omitting sex as a covariate did not change the significance levels reported below.

Valence. Overall, the two-level model explained over half of the variance in self-reported valence at the level of image type, $pseudo R^2_{Level 1} = .57$ and a modest amount at the level of the individual participant, $pseudo R^2_{Level 2} = .07$ (Cohen, 1992; Edwards et al., 2008). The MLM for valence revealed a significant main effect of image type, $F(2, 294) = 97.04$, $p < .001$, $R^2_\beta = 0.398$, which was qualified by the two-way interactions between Image Type $\times$ Extraversion, $\chi^2(2) = 8.03$, $p = .018$, and Image Type $\times$ Writing Condition interaction, $\chi^2(2) = 7.69$, $p = .021$, respectively. Unlike Study 1, the Writing Condition $\times$ Neuroticism interaction, $F(1, 294) = 0.146$, $p = .702$, $R^2_\beta < 0.001$, and the Image Type $\times$ Writing Condition $\times$ Extraversion interaction, $F(2, 294) = 1.35$, $p = .260$, $R^2_\beta = 0.009$, were both non-significant. See Table 4.

We probed the simple effects of the two significant interactions separately within each image type. For the Image Type $\times$ Extraversion interaction, higher extraversion predicted more positive valence in response to positive images, $B = 0.020$, $SE(B) = 0.005$, $p < .001$, and more negative valence in response to negative images, $B = -0.011$, $SE(B) = 0.005$, $p = .044$.

Extraversion did not relate to valence responses to neutral images, $B = 0.005$, $SE(B) = 0.004$, $p = .198$.

For the Image Type $\times$ Writing Condition interaction, writing condition predicted valence in response to positive images, $B = 0.218$, $SE(B) = 0.082$, $p = .008$, such that participants reported experiencing more positive valence in the controlled writing condition than in the free writing condition. Writing condition had no significant effect on valence responses to negative images, $B = -0.133$, $SE(B) = 0.090$, $p = .141$, or neutral images, $B = 0.128$, $SE(B) = 0.066$, $p = .053$. See Figure 2.

To be consistent with Study 1, we probed the interaction between extraversion and writing condition on positive reactivity. As in Study 1, valence responses to positive images increased with extraversion in the controlled writing condition, $B = 0.025$, $SE(B) = 0.007$, $p < .001$. Unlike Study 1, however, valence in response to positive images also increased with extraversion in the free writing condition, $B = 0.015$, $SE(B) = 0.007$, $p = .033$. See Figure 3.

As in Study 1, we again tested the effect of writing condition on valence responses to positive images at high (+1 *SD*) and low (-1 *SD*) levels of extraversion. The effect of writing condition was significant at high extraversion, $B = 0.294$, $SE(B) = 0.113$, $p = .009$, but not at low extraversion, $B = 0.143$, $SE(B) = 0.111$, $p = .199$. Neyman-Johnson regions of significance revealed that the effect of controlled writing on positive reactivity was significant among individuals from 0.21 standard deviations below the mean to 2.66 standard deviations above the mean extraversion score (this upper value exceeds the top range of the scale). Thus, the effect of controlled writing on subsequent valence responses to positive images emerged among individuals who were just below to well above the mean extraversion score in this sample.

Arousal. Overall, the two-level model explained a moderate portion of the variance in self-reported arousal at the level of image type, $pseudo R^2_{Level 1} = .38$, and at the level of the individual participant, $pseudo R^2_{Level 2} = .09$ (Cohen, 1992; Edwards et al., 2008). The MLM for arousal revealed significant main effects of image type, $F(2, 294) = 178.72, p < .001, R^2_{\beta} = 0.549$, extraversion, $F(1, 294) = 15.187, p < .001, R^2_{\beta} = 0.049$, and neuroticism, $F(1, 294) = 14.923, p < .001, R^2_{\beta} = 0.078$, which were qualified by the Writing Condition $\times$ Image Type interaction, $F(2, 294) = 3.88, p = .021, R^2_{\beta} = 0.026$, and the Image Type $\times$ Extraversion interaction, $F(2, 294) = 3.04, p = .048, R^2_{\beta} = 0.020$. All other effects were non-significant; see Table 4.

We probed the simple effects of the two significant interactions separately within each image type. For the Image Type $\times$ Extraversion interaction, arousal in response to positive images increased with extraversion, $B = 0.034, SE(B) = 0.008, p < .001$, as did arousal in response to neutral images, $B = 0.018, SE(B) = 0.006, p = .003$, but not in response to negative images, $B = 0.015, SE(B) = 0.010, p = .123$. For the Writing Condition $\times$ Image Type interaction, writing condition influenced arousal such that participants reported experiencing higher arousal to positive images in the controlled writing condition than in the free writing condition, $B = 0.355, SE(B) = 0.124, p = .004$. Writing condition did not influence arousal in response to negative images, $B = 0.047, SE(B) = 0.152, p = .758$, or neutral images, $B = 0.057, SE(B) = 0.099, p = .563$. See Figure 4.

Discussion

The results from Study 2 were broadly consistent with the results from Study 1, such that exercising self-control at Time 1 increased positive emotional reactivity at Time 2. In Study 1, the increase in positive emotional reactivity was moderated by trait extraversion (i.e., only more

extraverted individuals showed increased positive reactivity after exercising self-control), but in Study 2 the increase in positive emotional reactivity was not moderated by extraversion (i.e., positive reactivity increased after exercising self-control across a wider range of extraversion scores). Further, whereas prior self-control did not influence arousal in Study 1, in Study 2 we found that arousal increased in response to positive images after the controlled writing task compared to the free writing task. The evidence that exercising self-control increased both positive valence and arousal in response to pleasant images is consistent with the process model of ego depletion, which predicts that self-control triggers a subsequent shift in motivation and attention toward more positive events.

We did not replicate in Study 2 the unexpected neuroticism finding from Study 1, whereby prior self-control reduced the association between neuroticism and valence across image types. That finding, which we had not anticipated in Study 1, seems likely to have been a spurious result.

General Discussion

The aftereffects of self-control have been studied extensively from a limited resource perspective. Numerous experiments have found that exercising self-control temporarily undermines success at subsequent acts of self-control, resulting in more aggressive responding to provocation, poorer performance on tests of attention control, and reduced persistence at difficult tasks (for a review, see Baumeister & Vohs, 2016b). Those findings are consistent with the idea that exercising self-control at Time 1 depletes some limited inner resource or strength needed for further self-control at Time 2. However, the resource model has been challenged on both empirical and conceptual grounds, including some notable failures to replicate (see Friese et al., in press).

The present investigation focused on the aftereffects of self-control for non-controlled responding. Specifically, in two well-powered experiments we manipulated the exercise of self-control and then had participants simply view and respond to positive, negative, or neutral photographic images. The state of the limited resource for self-control should be irrelevant during passive picture viewing because participants are under no obligation to control their emotional responses, but we found that exercising self-control at Time 1 influences positive emotional reactivity at Time 2.

In Study 1, performing a controlled writing task boosted the subsequent experience of positive emotional valence in response to positive images only among individuals higher in extraversion. In Study 2, performing the controlled writing task increased both positive valence and arousal in response to positive images regardless of trait extraversion. Exercising self-control had no consistent aftereffects on emotional responses to negative or neutral images. These findings are not readily explained by the resource model of self-control. If anything, the resource model would suggest that exercising self-control increases negative emotional reactivity, insofar as the spontaneous down-regulation of negative emotion is reduced under ego depletion, but we found that negative reactivity was unaffected by the prior exercise of self-control.

The observed changes in emotional reactivity are more consistent with a process model of ego depletion, which proposes that exercising self-control causes shifts in motivation and attention toward potential rewards (Inzlicht & Schmeichel, 2012; Inzlicht et al., 2014). In this view, self-control is a frustrating or otherwise aversive endeavor that motivates individuals to seek out more pleasant emotional events. In the pilot study we found support for the idea that exercising self-control is a frustrating and effortful activity. We propose that frustrating acts of self-control may subsequently bias individuals toward more pleasant “want-to” tasks (Inzlicht et

al., 2014; Milyavskaya, Inzlicht, Hope, & Koestner, 2015), presumably out of a desire to achieve a more pleasant emotional state, thereby leading to an increase in positive emotional reactivity.

The current studies complement and advance prior research in three ways. First, these studies revealed aftereffects of self-control for subjective emotional experience, thereby extending past evidence that exercising self-control influences neural indices of motivational orientation (Schmeichel et al., 2016). Second, the current studies tested more participants and thus achieved greater statistical power than previous work, and one of the current studies was a preregistered replication, which reduces experimenter degrees of freedom and Type I error rates. The current research thus used stronger, more transparent research practices relative to previous work. And third, the current findings represent conceptual replications of prior evidence that exercising self-control increases reward sensitivity. The convergent evidence that has emerged across distinct methods of investigation increases confidence in the predictions based on the process model of ego depletion.

Individual differences in the aftereffects of self-control

The current findings underscore the role of individual differences in understanding the aftereffects of self-control. Most published research on ego depletion has observed main effects (see Hagger et al., 2010). But most prior research, unlike the current studies, used self-control tasks as the dependent measure. The current findings join with other recent evidence to suggest the aftereffects of self-control may extend to non-controlled responding, and that such aftereffects are moderated by associated traits. For example, Crowell et al. (2014) found that exercising self-control increases personal optimism and attentional breadth, but only among individuals high in approach motivation (who are prone to optimism and to broadened attentional scope; Anderson & Galinsky, 2006; Förster et al., 2006). Insofar as exerting self-control shifts

attention and motivation toward hedonism or good feelings, individual differences in reward sensitivity, positive emotionality, and related constructs are likely to moderate the aftereffects, particularly when the Time 2 task taps reward-related responding.

The aftereffects of self-control hinged on individual differences in extraversion in Study 1, such that only more extraverted individuals showed an increase in positive reactivity. In Study 2, more extraverted individuals again showed more positive reactivity after exercising self-control, but less extraverted individuals did, too. Hence, the most consistent pattern across studies was increased positive emotional reactivity among more extraverted individuals. The main difference in the results across the studies was the relationship between extraversion and positive reactivity in the no depletion conditions. Extraversion did not relate to positive reactivity in the free writing condition in Study 1 but did relate to positive reactivity in the free writing condition in Study 2. These different relationships between extraversion and positive reactivity in the absence of prior self-control mirror past research, which sometimes has and sometimes has not found a relationship between extraversion and positive reactivity (e.g., Lucas & Baird, 2004).

Extraversion may be especially likely to influence positive emotional reactivity to appetitive or arousing stimuli, congruent with the idea that extraversion reflects a predisposition toward approach motivation and reward sensitivity (Smillie, Cooper, Wilt, & Revelle, 2012; Smillie, DeYoung, & Hall, 2015). Indeed, we selected positive IAPS images that elicit both high positive valence and high arousal with the aim of tapping approach motivated positive affect. We propose that extraversion relates to positive emotional reactivity to appetitive stimuli particularly when approach motivation is activated or primed, such as after an effortful bout of self-control. Future research should consider the extent to which other states associated with an approach

orientation (e.g., anger, hunger) influence the relationship between extraversion and positive emotional reactivity.

Furthermore, given recent debates regarding the reliability of the ego depletion effect (Carter et al., 2015; Cunningham & Baumeister, 2016; Job, Dweck, & Walton, 2010; Vohs, Baumeister, & Schmeichel, 2012), it seems sensible to test potential moderators of self-control's aftereffects. We have suggested that moderation by extraversion (and related traits like approach motivation) is likely specific to reward-related dependent measures. For other types of dependent measures, such as those that involve careful thinking or cognitive control, individual differences in cognitively-oriented traits, such as need for cognition or action orientation, may be more relevant (e.g., Gröpel, Baumeister, & Beckmann, 2014). We encourage further research to consider the impact of pertinent traits when assessing the aftereffects of self-control.

Limitations and Future Directions

The process model proposes that exercising self-control causes shifts in attention and motivation toward rewarding stimuli, but it is unclear whether motivation or attention explains the current findings. Perhaps exercising self-control causes extraverted persons to attend more closely to positive images, or perhaps exercising self-control changes how individuals attend to their emotional reactions. Exercising self-control may also have increased reward sensitivity among more extraverted individuals. Additional research is needed to determine the extent to which exercising self-control alters emotional reactivity mainly due to shifts in attention or motivation (especially reward sensitivity).

The current research was also limited insofar as we assessed emotional reactivity using single-item SAM measures of valence and arousal after each picture. These measures are commonly used to track emotional responding to IAPS images (Caria, Sitaram, Veit,

Begliomimi, & Birbaumer, 2010; Lang, Bradley, & Cuthbert, 2005; Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011), and they permit relatively fast and unobtrusive responses to multiple stimuli. But emotional responding is complex and entails more than just the two dimensions of valence and arousal (e.g., Cowen & Keltner, 2017; Fontaine, Scherer, Roesch, & Ellsworth, 2007; Tellegen, Watson, & Clark 1999). We used multilevel modeling to capitalize on our decision to assess valence and arousal in response to several emotional stimuli, but the single-item SAM measures may have missed relevant aspects of emotional responding (e.g., parsing different forms of positive reactivity, such as excitement versus interest). Further insight may be gained by using more nuanced measures to assess the emotional aftereffects of self-control.

Additionally, the current research used a limited range of picture stimuli to elicit positive affect. We selected positive IAPS images that elicit both positive valence and high arousal, including primarily pictures of appetitive objects and activities. Individuals higher in extraversion appear to be more responsive to events that elicit positive activation (Smillie et al., 2015), and we deemed the selected pictures to be pertinent to this responsivity. The current research is, however, uninformative regarding the impact of prior self-control exertion on responses to stimuli that elicit other forms of positive affect (e.g., low arousal positive affects such as contentment or relaxation). Prior research has found that self-control exertion causes individuals to prioritize rest, which represents a low arousal (low activation) positive affective state (Job, Bernecker, Miketta, & Friese, 2015). Future research is needed to assess the possibility of more nuanced aftereffects of self-control on a wider range of positive emotional events. We suspect that exerting self-control results in more versus less activated positive emotional reactivity depending on the salience of rewarding or arousing positive events.

The current research is also limited by the fact that we did not assess participants' subjective responses to the manipulation of self-control at Time 1. The pilot study affirmed that the controlled writing task was frustrating and effortful, and we suspect these characteristics of exercising self-control are integral to the observed increases in positive emotional reactivity at Time 2. But we decided not to assess subjective experiences of the Time 1 task during the main studies because asking participants to reflect upon their internal states may have influenced how they subsequently responded to the main dependent measure at Time 2 (i.e., the pictures). Manipulation checks may act as a manipulation (Hauser, Ellsworth, & Gonzalez, 2018). Indeed, prior research has observed that responses to emotional events can be altered by first asking participants to reflect on and report their subjective emotional experience (Kassam, & Mendes, 2013; see also Berkowitz, Jaffee, Jo, & Troccoli, 2000). We also decided against asking participants to reflect back on their subjective experiences at the end of the experiment because such responses are susceptible to errors in memory and to other fallibilities in reporting prior subjective experiences (e.g., Thomas & Diener, 1990). Lacking direct measures of feelings of effort and averseness following the writing task, however, it is impossible to test these states as possible mechanisms for the increased positive reactivity observed in the current experiments. Additional research is needed.

Additional research is also needed to examine how the emotional aftereffects of self-control influence behavior. The present results may suggest a potential alternative explanation for self-control failures typically attributed to ego depletion—increased positive reactivity. For example, if exerting self-control causes appetitive stimuli such as candy, alcohol, and cigarettes to be enjoyed even more than usual, then this may help to explain why individuals act against their long-term goals and experience a momentary failure of self-control under ego depletion.

The present results further suggest that some of the inconsistent results that have cropped up in the ego depletion literature may be due to the use of dependent measures unrelated to positive reactivity. Based on the process model and the current results, we suggest that the ego depletion effect is most likely to emerge for Time 2 tasks that entail the control of reward-related or appetitive impulses.

Linking subjective experiences and behavioral consequences will paint a more complete picture of self-control's aftereffects and may suggest novel avenues for interventions to improve self-control. Insofar as increases in positive reactivity reflect an underlying increase in approach motivation and reward-seeking, we would also expect increases in the intensity of other approach-related responses, including anger and aggression (Harmon-Jones, 2003; Carver & Harmon-Jones, 2009). Indeed, some evidence suggests that prior efforts at self-control increase acts of aggression (DeWall, Baumeister, Stillman, Gailliot, 2007; Stucke & Baumeister, 2006). Future research should probe the extent to which the aversive nature of self-control motivates hedonic-oriented emotion regulation, including perhaps anger and aggression, to restore positive affect. This pattern would imply that one way to mitigate the aftereffects of self-control may be to make self-control less aversive (for example, by providing rewards or other encouragements for exerting self-control). Indeed, this perspective is congruent with evidence that positive affective events may counteract some of the behavioral aftereffects of self-control (Tice, Baumeister, Shmueli, & Muraven, 2007).

Conclusions

Increased scrutiny and skepticism regarding the ego depletion effect has cast doubt on the validity of the limited resource model of self-control. We maintain that exercising self-control has consequential aftereffects, but these may not be the consequence of a depleted resource. The

current studies revealed aftereffects of self-control beyond tasks that require self-control. Indeed, self-control exertion influenced spontaneous, non-controlled emotional responding during a passive image viewing task in the current studies, such that more extraverted persons experienced more positive emotion. This pattern of results supports the process model of ego depletion and suggests that the aftereffects of self-control may be studied and understood without reference to limited resources.

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Figure 1. Average valence response to positive images as a function of writing condition and extraversion, controlling for neuroticism and sex of participant in Study 1. Higher numbers indicate more positive valence. Error bars represent standard errors.

Figure 2. Average valence response to each image type as a function of writing condition, controlling for neuroticism, extraversion, and sex of participant in Study 2. Higher numbers indicate more positive valence. Error bars represent standard errors. ** $p < .01$

Figure 3. Average valence response to positive images as a function of writing condition and extraversion, controlling for neuroticism and sex of participant in Study 2. Higher numbers indicate more positive valence. Error bars represent standard errors.

Figure 4. Average arousal response to each image type as a function of writing condition, controlling for neuroticism, extraversion, and sex of participant in Study 2. Higher numbers indicate more arousal. Error bars represent standard errors. ** $p < .01$

Table 1. Descriptive Statistics and Correlations by Writing Condition (Study 1)

	<i>M</i>	<i>SD</i>	Correlations							
			1	2	3	4	5	6	7	8
1. Extraversion	31.78	8.17	-	-.21*	.13	.11	.03	.01	.00	-.03
2. Neuroticism	30.12	6.83	-.01	-	-.22*	-.15	-.14	.07	-.19*	.04
3. Negative Image, Valence	2.03	0.82	-.09	-.11	-	-.12	-.03	-.11	.17	.11
4. Negative Image, Arousal	4.62	1.31	.17	.10	-.13	-	.13	.17	.38**	.04
5. Positive Image, Valence	5.24	0.74	.25**	.08	.03	.21*	-	.46**	.14	.07
6. Positive Image, Arousal	4.45	1.05	.22*	.14	-.15	.26**	.59**	-	-.09	.44**
7. Neutral Image, Valence	4.04	0.55	.14	-.02	-.06	.03	.27**	.09	-	.15
8. Neutral Image, Arousal	2.33	0.92	.09	.08	-.04	-.01	.17	.51**	.21*	-

Note. Means and standard deviations are for the overall sample ($n = 256$). Correlations above the diagonal are from the free writing condition, and correlations below the diagonal are from the controlled writing condition.

* $p < .05$, ** $p < .01$

Table 2. Multilevel model coefficients (Study 1)

Effects	Estimate(SE)	Valence MLM			R^2_β	Arousal MLM			
		p	95% CI			Estimate(SE)	p	95% CI	R^2_β
Intercept	3.779(0.027)	<.001	[3.725, 3.833]			3.810 (0.048)	<.001	[3.716, 3.903]	
Sex	-0.044(0.029)	.126	[-0.101, 0.013]	0.009		-0.055(0.046)	0.232	[-0.145, 0.035]	0.006
Writing Condition	0.029(0.027)	.284	[-0.024, 0.081]	0.005		0.074(0.046)	.111	[-0.017, 0.164]	0.010
Image Type, Positive	1.470(0.035)	<.001	[1.402, 1.537]	0.878		0.654(0.041)	<.001	[0.573, 0.736]	0.500
Image Type, Negative	-1.742(0.039)	<.001	[-1.818, -1.666]	0.889		0.815(0.060)	<.001	[0.697, 0.934]	0.421
Extraversion	0.005(0.003)	.092	[-0.001, 0.011]	0.011		0.014(0.006)	.016	[0.003, 0.025]	0.023
Neuroticism	-0.010(0.004)	.015	[-0.018, -0.002]	0.023		0.007(0.007)	.358	[-0.008, 0.021]	0.003
Writing X Image Type, Positive	0.005(0.035)	.884	[-0.063, 0.073]	< 0.001		-0.031(0.041)	.450	[-0.112, 0.050]	0.002
Writing X Image Type, Negative	0.020(0.039)	.606	[-0.056, 0.096]	0.001		0.007(0.060)	.909	[-0.111, 0.125]	< 0.001
Writing X Extraversion	0.004(0.003)	.231	[-0.002, 0.010]	0.006		0.009(0.006)	.127	[-0.002, 0.020]	0.009
Writing X Neuroticism	0.009(0.004)	.024	[0.001, 0.017]	0.020		0.010(0.007)	.179	[-0.005, 0.024]	0.007
Extraversion X Image, Positive	0.008(0.004)	.071	[-0.001, 0.016]	0.013		0.003(0.005)	.538	[-0.007, 0.013]	0.002
Extraversion X Image, Negative	-0.006(0.005)	.216	[-0.015, 0.003]	0.006		0.006(0.007)	.358	[-0.007, 0.020]	0.003
Neuroticism X Image, Positive	0.007(0.005)	.179	[-0.003, 0.018]	0.007		0.011(0.007)	.137	[-0.003, 0.024]	0.009
Neuroticism X Image, Negative	-0.008(0.006)	.141	[-0.020, 0.003]	0.009		-0.013(0.011)	.234	[-0.033, 0.008]	0.006
Condition X Extraversion X Image, Positive	0.009(0.004)	.024	[0.001, 0.018]	0.020		0.005(0.005)	.345	[-0.005, 0.015]	0.004
Condition X Extraversion X Image, Negative	-0.012(0.005)	.010	[-0.021, -0.003]	0.026		-0.003(0.007)	.662	[-0.017, 0.011]	0.001
Condition X Neuroticism X Image, Positive	0.003(0.005)	.573	[-0.008, 0.014]	0.001		-0.006(0.007)	.392	[-0.020, 0.008]	0.003
Condition X Neuroticism X Image, Negative	-0.002(0.006)	.679	[-0.014, 0.009]	< 0.001		0.013(0.011)	.206	[-0.007, 0.034]	0.006
Valence						Arousal			
<i>Pseudo R²</i> Level 1: .542, Level 2: .075						<i>Pseudo R²</i> Level 1: .401, Level 2: .052			

Table 3 Descriptive Statistics and Correlations by Writing Condition (Study 2)

	<i>M</i>	<i>SD</i>	Correlations							
			1	2	3	4	5	6	7	8
1. Extraversion	31.68	7.97	-	-.16*	-.04	.08	.16	.23**	.04	.12
2. Neuroticism	20.27	7.24	-.22**	-	.03	.14	.00	.08	-.14	.13
3. Negative Image, Valence	2.04	0.83	-.19*	-.09	-	-.47**	-.21**	-.11	-.13	.12
4. Negative Image, Arousal	4.49	1.35	.06	.09	-.31**	-	.33**	.38**	.30**	.20*
5. Positive Image, Valence	5.17	0.73	.25**	.03	-.15	.31**	-	.53**	.23**	.13
6. Positive Image, Arousal	4.24	1.14	.19*	.22**	-.30**	.36**	.59**	-	-.08	.50**
7. Neutral Image, Valence	4.07	0.58	.10	-.03	.03	.15	.36**	.08	-	.10
8. Neutral Image, Arousal	2.27	0.88	.16	.12	-.09	.23**	.25**	.53**	.21*	-

Note. Means and standard deviations are for the overall sample ($n = 301$). Correlations above the diagonal are from the free writing condition, and correlations below the diagonal are from the controlled writing condition.

* $p < .05$, ** $p < .01$

Table 4 Multilevel model coefficients (Study 2)

Effects	Estimate(SE)	Valence MLM			R^2_{β}	Arousal MLM			
		p	95% CI			Estimate(SE)	p	95% CI	R^2_{β}
Intercept	3.796(0.022)	<.001	[3.753, 3.839]			3.665 (0.050)	<.001	[3.567, 3.763]	
Sex	-0.099(0.026)	<.001	[-0.150, -0.048]	0.047		0.032(0.049)	0.520	[-0.065, 0.128]	0.001
Writing Condition	0.036(0.023)	.117	[-0.009, 0.080]	0.008		0.076(0.047)	.100	[-0.015, 0.168]	0.009
Image Type, Positive	1.418(0.032)	<.001	[1.355, 1.481]	0.869		0.574(0.038)	<.001	[0.500, 0.648]	0.442
Image Type, Negative	-1.731(0.039)	<.001	[-1.807, -1.655]	0.870		0.827(0.051)	<.001	[0.727, 0.927]	0.472
Extraversion	0.005(0.003)	.058	[-0.000, 0.010]	0.012		0.022(0.006)	<.001	[0.011, 0.034]	0.049
Neuroticism	0.002(0.003)	.559	[-0.001, 0.008]	0.001		0.027(0.007)	<.001	[0.013, 0.041]	0.048
Writing X Image Type, Positive	0.074(0.032)	.022	[0.011, 0.137]	0.017		0.101(0.038)	.007	[0.027, 0.175]	0.024
Writing X Image Type, Negative	-0.102(0.039)	.009	[-0.202, -0.026]	0.023		-0.053(0.051)	.299	[-0.153, 0.047]	0.004
Writing X Extraversion	<0.001(0.002)	.989	[-0.005, 0.005]	< 0.001		-0.001(0.006)	.921	[-0.012, 0.011]	< 0.001
Writing X Neuroticism	0.001(0.003)	.702	[-0.005, 0.008]	< 0.001		0.005(0.007)	.465	[-0.008, 0.018]	0.002
Extraversion X Image, Positive	0.015(0.004)	<.001	[0.007, 0.024]	0.046		0.012(0.005)	.016	[0.002, 0.022]	0.019
Extraversion X Image, Negative	-0.016(0.005)	.001	[-0.025, -0.007]	0.037		-0.007(0.007)	.262	[-0.020, 0.006]	0.004
Neuroticism X Image, Positive	0.008(0.005)	.100	[-0.001, 0.017]	0.009		0.011(0.007)	.137	[-0.007, 0.014]	0.005
Neuroticism X Image, Negative	-0.003(0.006)	.597	[-0.015, 0.008]	0.001		-0.013(0.011)	.234	[-0.009, 0.018]	< 0.001
Condition X Extraversion X Image, Positive	0.005(0.004)	.246	[-0.003, 0.013]	0.005		-0.001(0.005)	.834	[-0.014, 0.012]	< 0.001
Condition X Extraversion X Image, Negative	-0.007(0.005)	.104	[-0.017, 0.002]	0.009		-0.001(0.007)	.825	[-0.017, 0.011]	< 0.001
Condition X Neuroticism X Image, Positive	0.003(0.005)	.512	[-0.006, 0.012]	0.001		0.006(0.005)	.233	[-0.011, 0.009]	0.005
Condition X Neuroticism X Image, Negative	-0.008(0.006)	.180	[-0.019, 0.004]	0.006		-0.002(0.007)	.465	[-0.016, 0.034]	< 0.001
Valence					Arousal				
<i>Pseudo R²</i> Level 1: .571, Level 2: .072					<i>Pseudo R²</i> Level 1: .381, Level 2: .088				

Supplemental Materials and Appendix for Finley & Schmeichel (2018). Aftereffects of self-control on positive emotional reactivity. *Personality and Social Psychology Bulletin*.

All analyses regarding self-reported efforts to change emotional responses, as well as exploratory analyses examining the moderating effects of trait self-control, are reported in the supplemental materials below. MPlus syntax for the multilevel models for both studies follows in the Appendix.

Study 1

Self-reported efforts to change emotional responses. A hierarchical regression on self-reported efforts to increase emotions to positive images revealed only a significant effect of extraversion, $B = 0.036$, $SE(B) = 0.015$, $p = .013$, 95% CI [0.008, 0.065], $\Delta R^2 = .024$; more extraverted individuals reported more efforts to increase emotions to positive images. The effects of neuroticism, $p = .084$, writing condition, $p = .434$, and the interaction terms, $ps > .350$, were non-significant.

The same analysis on self-reported efforts to decrease emotions to negative images revealed only a marginal effect of neuroticism, $B = 0.031$, $SE(B) = 0.016$, $p = .051$, 95% CI [< 0.001 , 0.062], $\Delta R^2 = .015$; more neurotic individuals tended to report more effort to decrease emotions to negative emotions. There was no effect of extraversion, $p = .081$, writing condition, $p = .566$, or the interactions, $ps > .100$.

Exploratory analyses examining moderation by trait self-control. At the request of reviewers, we explored the extent to which trait self-control moderates the aftereffects of self-control on emotional responses by replacing extraversion (and neuroticism) with trait self-control as the individual difference moderator in the multilevel model analyses reported in the main

manuscript. See Table S1 for the full results. For self-reported valence in Study 1, we found no significant interactions between trait self-control and writing condition, $ps > .200$, suggesting that trait self-control did not moderate the emotional aftereffects of self-control.

For self-reported arousal in Study 1 we found a main effect of trait self-control, $F(1, 251) = 3.80, p < .001, R^2_{\beta} = 0.055$, such that individuals higher in trait self-control reported less arousal, which was qualified by a trait self-control by condition interaction, $F(2, 250) = 2.89, p < .004, R^2_{\beta} = 0.032$. To decompose the interaction, we examined the simple slopes of trait self-control and condition at each image type (even though the three-way interaction with image type was not significant, $p > .200$). As shown in Figure S1, in the free writing condition trait self-control did not relate to arousal in response to positive, $B = -0.049, SE(B) = 0.117, p = .676$, negative, $B = -0.071, SE(B) = 0.185, p = .699$, or neutral images, $B = -0.080, SE(B) = 0.114, p = .486$, but in the controlled writing condition individuals higher in trait self-control reported less arousal particularly in response to negative, $B = -0.678, SE(B) = 0.196, p = .001$, and positive images, $B = -0.464, SE(B) = 0.172, p = .007$, but not neutral images, $B = -0.152, SE(B) = 0.155, p = .357$.

Figure S1: Self-reported arousal in Study 1 as a function of image type, condition, and trait self-control.

Study 2

Self-reported efforts to change emotional responses. A hierarchical regression on self-reported efforts to increase emotions to positive images revealed only a significant effect of neuroticism, $B = 0.033$, $SE(B) = 0.016$, $p = .033$, 95% CI [0.003, 0.064], $\Delta R^2 = .012$; more neurotic individuals reported more effort to increase emotions to positive images. The effects of extraversion, $p = .099$, writing condition, $p = .303$, and the interaction terms, $ps > .150$, were non-significant; however the effect of extraversion was in the same direction as in Study 1, $B = 0.023$, $SE(B) = 0.014$, $p = .099$, 95% CI [-0.004, 0.051], $\Delta R^2 = .005$.

The same analysis on self-reported efforts to decrease emotions to negative images revealed a significant effect of neuroticism, $B = 0.034$, $SE(B) = 0.013$, $p = .012$, 95% CI [0.008, 0.060], $\Delta R^2 = .012$, a significant effect of extraversion, $B = 0.041$, $SE(B) = 0.012$, $p = .001$, 95% CI [0.017, 0.064], $\Delta R^2 = .033$, and a marginal effect of writing condition, $B = 0.359$, $SE(B) = 0.188$, $p = .057$, 95% CI [-0.011, 0.729], $\Delta R^2 = .012$, which were in turn qualified by a significant extraversion by writing condition interaction, $B = 0.056$, $SE(B) = 0.024$, $p = .020$, 95% CI [0.009, 0.103], $\Delta R^2 = .019$, all other interactions were non-significant, $ps > .500$. Simple slope analyses revealed that, in the free writing condition, extraversion was not related to efforts to decrease emotions to negative images, $B = 0.014$, $p = 0.387$. In the controlled writing condition, extraversion was related to efforts to decrease emotions to negative images, such that individuals higher in extraversion reported more effort to reduce negative emotions, $B = 0.070$, $p < 0.001$. See Figure S2.

Figure S2. Average self-reported efforts to decrease emotional responses to negative images as a function of writing condition and extraversion, controlling for neuroticism, from Study 2.

Exploratory analyses examining moderation by trait self-control. We again conducted exploratory analyses parallel to those reported in Study 1, examining the extent to which trait self-control moderates the aftereffects of self-control on subsequent emotional responding. See Table S2. For self-reported valence in Study 2, we found a significant main effect of trait self-control, $F(1, 295) = 2.06$, $p = .039$, $R^2_{\beta} = 0.017$, such that individuals higher in trait self-control responded with less positive valence to all images. We found no interactions between condition and trait self-control, $ps > .400$, suggesting that trait self-control did not moderate the aftereffects of self-control on emotional responding.

Further, for self-reported arousal in Study 2, unlike in Study 1, we found neither a main effect of trait self-control, $F(1, 295) = 0.56$, $p = .576$, $R^2_{\beta} = 0.001$, nor a trait self-control by

condition interaction, $F(2, 295) = 1.38, p = .168, R^2_{\beta} = 0.008$. The three-way picture type by condition by trait self-control interaction was also non-significant, $p = .650$, again suggesting no moderation by trait self-control.

To be consistent with Study 1, we examined the simple slopes of trait self-control and condition at each image type (even though the three-way interaction with image type was not significant). As shown in Figure S3, the pattern of findings were different from Study 1, such that trait self-control related to less arousal in response to positive images in the free writing condition, $B = -0.311, SE(B) = 0.117, p = .008$, but not in the controlled writing condition, $B = -0.053, SE(B) = 0.128, p = .678$. For negative images, the relationship between trait self-control and arousal was reversed in the controlled writing condition, such that individuals higher in trait self-control reported (non-significantly) more arousal, $B = 0.204, SE(B) = 0.170, p = .230$, and there was no relationship with arousal to negative images in the free writing condition, $B = -0.009, SE(B) = 0.161, p = .954$. For neutral image, we found no relationships to trait self-control in the free writing condition, $B = -0.075, SE(B) = 0.109, p = .489$, or the controlled writing condition, $B = 0.020, SE(B) = 0.109, p = .852$.

Figure S3: Self-reported arousal in Study 2 as a function of image type, condition, and trait self-control

Table S1 Multilevel model coefficients for exploratory trait self-control analyses (Study 1)

Effects	Valence MLM				Arousal MLM			
	Estimate(SE)	<i>p</i>	95% CI	R ² _β	Estimate(SE)	<i>p</i>	95% CI	R ² _β
Intercept	3.781(0.028)	<.001	[3.726, 3.837]		3.788 (0.047)	<.001	[3.696, 3.880]	
Sex	0.021(0.028)	.103	[-0.106, 0.010]	0.011	-0.019 (0.047)	0.682	[-0.111, 0.072]	0.001
Writing Condition	0.021 (0.028)	.446	[-0.033, 0.076]	0.002	0.052 (0.046)	.257	[-0.038, 0.141]	0.006
Image Type, Positive	1.418(0.032)	<.001	[1.394, 1.529]	0.878	0.650 (0.043)	< .001	[0.566, 0.734]	0.477
Image Type, Negative	-1.731(0.039)	<.001	[-1.809, -1.652]	0.882	0.792 (0.099)	< .001	[0.685, 0.931]	0.400
Trait Self-Control	-0.043(0.047)	.355	[-0.135, 0.048]	0.003	-0.248 (0.065)	< .001	[-0.377, -0.120]	0.055
Writing X Image Type, Positive	-0.007(0.035)	.842	[-0.075, 0.061]	< 0.001	-0.030 (0.043)	.491	[-0.114, 0.055]	0.002
Writing X Image Type, Negative	0.023(0.040)	.572	[-0.056, 0.101]	0.001	-0.009 (0.063)	.890	[-0.131, 0.114]	< 0.001
Writing X Trait Self-Control	-0.003(0.046)	.949	[-0.092, 0.086]	< 0.001	-0.183(0.063)	.004	[-0.306, 0.059]	0.032
Trait Self-Control X Image, Positive	-0.143 (0.052)	.006	[-0.245, -0.041]	0.029	-0.008(0.075)	.919	[-0.155, 0.139]	< 0.001
Trait Self-Control X Image, Negative	0.044(0.061)	.475	[-0.076, 0.163]	0.002	-0.125(0.112)	.262	[-0.345, 0.094]	0.005
Condition X Trait Self-Control X Image, Positive	-0.084(0.052)	.104	[-0.186, 0.017]	0.010	-0.025(0.075)	.739	[-0.172, 0.122]	< 0.001
Condition X Trait Self-Control X Image, Negative	0.110(0.061)	.071	[-0.009, 0.230]	0.012	-0.121(0.112)	.277	[-0.341, 0.098]	0.005
Valence					Arousal			
<i>Pseudo R</i> ² Level 1: .540, Level 2: .029					<i>Pseudo R</i> ² Level 1: .403, Level 2: .071			

Table S2 Multilevel model coefficients for exploratory trait self-control analyses (Study 2)

Effects	Valence MLM				Arousal MLM			
	Estimate(SE)	<i>p</i>	95% CI	R ² _β	Estimate(SE)	<i>p</i>	95% CI	R ² _β
Intercept	3.781(0.028)	<.001	[3.751, 3.837]		3.788 (0.047)	<.001	[3.547, 3.752]	
Sex	0.021(0.028)	.103	[-0.145, -0.044]	0.050	-0.019 (0.047)	0.682	[-0.016, 0.175]	0.011
Writing Condition	0.021 (0.028)	.446	[-0.011, 0.078]	0.009	0.052 (0.046)	.257	[-0.033, 0.157]	0.007
Image Type, Positive	1.418(0.032)	<.001	[1.350, 1.479]	0.881	0.650 (0.043)	< .001	[0.501, 0.649]	0.482
Image Type, Negative	-1.731(0.039)	<.001	[-1.803, -1.648]	0.884	0.792 (0.099)	< .001	[0.728, 0.927]	0.515
Trait Self-Control	-0.043(0.047)	.355	[-0.134, -0.003]	0.017	-0.248 (0.065)	< .001	[-0.172, 0.096]	0.001
Writing X Image Type, Positive	-0.007(0.035)	.842	[<0.001, 0.129]	0.015	-0.030 (0.043)	.491	[0.021, 0.169]	0.024
Writing X Image Type, Negative	0.023(0.040)	.572	[-0.169, -0.014]	0.021	-0.009 (0.063)	.890	[-0.149, 0.050]	0.004
Writing X Trait Self-Control	-0.003(0.046)	.949	[-0.043, 0.084]	0.002	-0.183(0.063)	.004	[-0.040, 0.228]	0.008
Trait Self-Control X Image, Positive	-0.143 (0.052)	.006	[-0.142, 0.053]	0.003	-0.008(0.075)	.919	[-0.259, -0.030]	0.024
Trait Self-Control X Image, Negative	0.044(0.061)	.475	[-0.191, 0.075]	0.003	-0.125(0.112)	.262	[-0.022, 0.291]	0.011
Condition X Trait Self-Control X Image, Positive	-0.084(0.052)	.104	[-0.026, 0.169]	0.008	-0.025(0.075)	.739	[-0.080, 0.149]	0.001
Condition X Trait Self-Control X Image, Negative	0.110(0.061)	.071	[-0.208, 0.057]	0.005	-0.121(0.112)	.277	[-0.145, 0.168]	< 0.001
Valence				Arousal				
<i>Pseudo R²</i> Level 1: .571, Level 2: .072				<i>Pseudo R²</i> Level 1: .368, Level 2: .020				

Appendix

Main Valence Multilevel Model Syntax for MPlus

```
listwise = on;

variable: names = SN Cond Extra Neur Val Ar PicVal PicValE1 PicValE2 CondE Gende
              ExC NxC;

missing = all (-999);

usevar = Extra Neur Val PicValE1 PicValE2 CondE Gende ExC NxC;

cluster = SN;

Within = PicValE1 PicValE2;

Between = Neur Extra Gende CondE ExC NxC;

analysis: type = twolevel random;

Model:

%within%

SL1Pos | Val on PicValE1;

SL2Neg | Val on PicValE2;

%Between%

SL1Pos on Neur Extra CondE ExC NxC;

SL2Neg on Neur Extra CondE ExC NxC;

Val on Neur Extra CondE Gende ExC NxC;

Val with SL1Pos SL2Neg;

SL1Pos with SL2Neg;

OUTPUT: stdyx modindices sampstat residual cinterval;
```

Main Arousal Multilevel Model Syntax for MPlus

```

listwise = on;

variable: names = SN Cond Extra Neur Val Ar PicVal PicValE1 PicValE2 CondE Gende
               ExC NxC;

missing = all (-999);

usevar = Extra Neur Ar PicValE1 PicValE2 CondE Gende ExC NxC;

cluster = SN;

Within = PicValE1 PicValE2;

Between =  Neur Extra Gende CondE ExC NxC;

analysis: type = twolevel random;

Model:

%within%

SL1Pos | Ar on PicValE1;

SL2Neg | Ar on PicValE2;

%Between%

SL1Pos on Neur Extra CondE ExC NxC;

SL2Neg on Neur Extra CondE ExC NxC;

Ar on Neur Extra CondE Gende ExC NxC;

Ar with SL1Pos SL2Neg;

SL1Pos with SL2Neg;

OUTPUT: stdyx modindices sampstat residual cinterval;

```

Exploratory Trait Self Control and Valence Multilevel Model Syntax for MPlus

```
listwise = on;

variable: names =  SN Extra Neur CondeE GendE ExC Nx C
PicValE1 PicValE2 Val Ar RT SC SCxC;

missing = all (-999);

usevar = CondeE GendE PicValE1 PicValE2 Val SC SCxC;

cluster = SN;

Within = PicValE1 PicValE2;

Between = SC CondeE GendE SCxC;

analysis: type = twolevel random;

Model:

%within%

SL1Pos | Val on PicValE1;

SL2Neg | Val on PicValE2;

%Between%

SL1Pos on SC CondeE SCxC;

SL2Neg on SC CondeE SCxC;

Val on SC CondeE GendE SCxC;

Val with SL1Pos SL2Neg;

SL1Pos with SL2Neg;

OUTPUT: stdyx modindices sampstat residual cinterval;
```

Exploratory Trait Self Control and Arousal Multilevel Model Syntax for MPlus

```

listwise = on;

variable: names =  SN Extra Neur CondeE GendE ExC Nx C
PicValE1 PicValE2 Val Ar RT SC SCxC;

missing = all (-999);

usevar = CondeE GendE PicValE1 PicValE2 Ar SC SCxC;

cluster = SN;

Within = PicValE1 PicValE2;

Between = SC CondeE GendE SCxC;

analysis: type = twolevel random;

Model:

%within%

SL1Pos | Ar on PicValE1;

SL2Neg | Ar on PicValE2;

%Between%

SL1Pos on SC CondeE SCxC;

SL2Neg on SC CondeE SCxC;

Ar on SC CondeE GendE SCxC;

Ar with SL1Pos SL2Neg;

SL1Pos with SL2Neg;

OUTPUT: stdyx modindices sampstat residual cinterval;

```