Endogenous emotion generation abilities support adaptive emotion management

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SHORT TITLE

ENDOGENOUS EMOTION GENERATION IN EMOTION REGULATION

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Abstract

Emotions are frequently thought of as reactions to events in the world. However, many of our emotional experiences are of our own making, coming from thoughts and memories. These different origins mean that these endogenous emotions are more controllable than exogenous emotions, making plausible a role of endogenous emotion in self-regulation and mental health.

We tested this idea in a representative sample of 277 individuals (163 female, 20-55 years) who partook in an experiment measuring individual differences in endogenous emotion generation ability and a questionnaire battery measuring individual differences in trait affect and emotional self-regulation style. Two hypotheses for how endogenous emotion generation can facilitate mental health were tested: By *buffering* negative stressors with self-generated positive emotion enabling use of emotion-focused regulation techniques, or by allowing effective *simulation* of the emotional consequences of future events, facilitating active and instrumental coping.

Support for both hypotheses was found. Consistent with *buffering*, positive emotion generation ability mediated the relationship between emotion-focused regulation and trait affect, while the ability to generate emotions regardless of valence, was found to mediate the relationship between active and instrumental regulation and trait affect, supporting a *simulation* account. This suggests role of emotion generation in emotion regulation, a finding of both theoretical and practical implication for mental health interventions.

There are more things likely to frighten us than there are to crush us; we suffer more often in imagination than in reality. – Seneca

Introduction

Emotions are often thought of as relatively automatic reactions, imparted on us by evolution and acculturation to enable adaptation to significant events in our environment (Ekman & Cordaro, 2011; Frijda, 2007). While this *exogenous* view of emotions is valuable in furthering our understanding of what emotions are and why they are important, it largely overlooks a large and important category of emotional phenomena that Seneca highlights, namely *endogenous* emotions. Such emotional states are not caused directly by external events, but rather by processes internal to the individual, such as thoughts and memories. Such endogenous emotional states include some of our most cherished and significant emotional experiences, ranging from existential dread and worrying about the future to savoring a cherished memory of a loved one. These states need to be studied separately from their exogenous cousins because, even if the distal causes of such experiences are environmental (e.g. your boss hints that you might be laid off), their proximate cause is endogenous (e.g. thoughts related to understanding what detriment this might mean for your career, finances, and your view of yourself as a valuable employee?). These different generation routes appear to be supported by separable neural mechanisms (at least partially; Engen, Kanske, & Singer, 2017), suggesting that endogenous emotion generation (EnGen) might serve different psychological functions than exogenous emotional states.

One important consideration pointing to differential functions is the observation that to the degree that we can control what we remember and think about, we can directly influence EnGen and, thus, what emotional states we experience. The upshot of this is that the adaptive value of emotional states might not be limited to adaptive reactions to exogenous events, but that they also can be used instrumentally to support goal achievement (Engen & Singer, 2018; Solomon, 2003). For instance, evidence suggests that volitional EnGen can be

used strategically to support emotional self-regulation. For instance, positive imagery can be used to counteract negative emotional reactions to external events (Engen & Singer, 2015), as well as altering internally maintained negative mood states in both normal and clinical populations (Blackwell & Holmes, 2010; Holmes, Coughtrey, & Connor, 2008; Holmes, Mathews, Dalgleish, & Mackintosh, 2006). Similarly, the tendency to engage in positive EnGen is associated with increased resilience (Fredrickson, 2013; Tugade & Fredrickson, 2004). As such, EnGen appears to serve an important emotion self-regulatory function with tangible mental health benefits.

However, precisely how these benefits might be imparted is unclear. One possibility, supported by the previously reviewed evidence, is that EnGen allows individuals to experience positive emotions in the absence of external appetitive stimuli, acting as a counter to negative and stressful external stimuli. If this *buffering hypothesis* (Engen & Singer, 2018; Tugade & Fredrickson, 2004) is correct, one would expect to find evidence that positive EnGen abilities are associated with an emotion management style (i.e. trait use of coping and emotion regulation techniques) that emphasizes on fostering positive emotional states (e.g. positive reappraisal), leading to more positive trait affect. Conversely, negative EnGen abilities might predispose one to experience more negative affect and might complicate efforts to use emotion management focused on increasing positive affect. Another possibility, albeit with less empirical support, is that EnGen abilities facilitate accurate simulation of the emotional relevance of future events (Aspinwall & Taylor, 1997; Bulley, Henry, & Suddendorf, 2017; Miloyan & Suddendorf, 2015; Miloyan, Bulley, & Suddendorf, 2018; Taylor & Schneider, 1989; Taylor, Pham, Rivkin, & Armor, 1998). According to this *simulation hypothesis*, EnGen enables prediction of what emotional stressors might occur and how to resolve them, allowing engagement in instrumental and active emotion management efforts (e.g. problem-solving, seeking support, proactive coping).

The current study tested the *buffering* and *simulation* hypotheses by investigating the relationship between a) individual differences in positive and negative EnGen abilities and b) trait affect and emotion management style as measured by questionnaire instruments. We did this by analyzing data from a previously reported dataset (Engen et al., 2017), where participants (N = 277) used self-chosen and idiosyncratically optimized techniques to generate both positive and negative emotional states (see Engen, Kanske, & Singer, 2018 for details on technique efficacy). The paradigm was developed specifically to gauge individual differences in emotion generation abilities, and we have previously shown that the paradigm elicits neural, psychophysiological, and behavioral responses consistent with the generation of strong subjective emotional states (Engen et al., 2017). Here we expand on our previous results by investigating the relationship between individual differences in EnGen abilities and participant self-report on an extensive battery of questionnaires measuring trait affect and emotion management styles, allowing us to directly test the *buffering* and *simulation* hypotheses proposed above.

As the hypotheses emphasize different facets of EnGen abilities, we investigated how both *relative* (i.e. positive minus negative) and *average* (i.e. average of positive *and* negative) EnGen abilities were related to self-reported trait affect and use of emotion management techniques. As the *buffering hypothesis* highlights the role of valence, support for it would imply finding that *relative* EnGen abilities were positively correlated with positive trait affect, as well as an emotion management style emphasizes increasing positive emotion in the face of negative stressors. Conversely, the *simulation hypothesis*, with its onus on accurate prediction rather than hedonics, would be supported if *average* EnGen abilities were associated with positive trait affect, as well as an emotion management style that involves instrumental and proactive approaches to deal with negative stressors.

Methods

Data availability statement

All data and scripts to replicate analyses using R are available online in the Open Science Foundation repository (<https://osf.io/8e7yz/>).

Participants

Data was acquired in the context of an fMRI study, neural data of which are reported elsewhere (Engen et al., 2017). Participants were recruited in the context of a large-scale longitudinal mental training project (The ReSource Project; for details see Singer et al., 2016), with the current report focusing on baseline data.

Eligibility for participation was determined using a screening procedure including SCID-I and II interviews performed by trained clinical psychologists, ensuring no ongoing mental health issues, and no life-time occurrence of psychotic or bipolar disorders, substance dependence, or any Axis-II disorders.

332 participants were recruited for the project, with 305 participants completing the current paradigm. Previous reports (Engen et al., 2018; 2017) used a subset of 293 participants, after excluding 5 participants due to missing data and technical difficulties and 4 participants reported difficulties (e.g. nausea or sleepiness) during the experiment, and a further 3 due to aberrant behavior suggestive of task non-compliance (e.g. low or no variance in behavioral ratings). Here, an additional 10 participants were excluded due to reporting stronger affect for the Neutral condition than the Generation conditions, suggesting they were unable to engage in EnGEn. Finally, 5 participants had incomplete questionnaire data, leaving a final sample of 277 (163 female, mean age=40.47, range: 20-55, SD=9.26) that were included in the current analysis. The study was approved by the Research Ethics Committees of the University of Leipzig (number 376/12-ff) and the Humboldt University, Berlin (numbers 2013-02, 2013-29, and 2014-10) and was carried out in compliance with the

Declaration of Helsinki. All participants gave written informed consent and were debriefed and paid after the longitudinal project was completed.

Training procedure

Before the experiment, participants underwent a supervised automated training session with two stages. First, participants underwent a multimodal affect induction procedure that provided examples of high and low arousal positive and negative emotion, ensuring that participants had similar representations of the target emotional states. Second, participants were introduced to four different modalities of emotion generation (Episodic Imagery, Semantic Analysis, Auditory Imagery, and Bodily Interoception), based on previous literature showing they are effective means of self-inducing emotion (see Engen et al., 2018 for details).

Participants freely selected one or more modalities to generate emotions and were also given the option to use self-formulated generation methods, the sole criterion being that they should choose a combination that best enabled them to generate emotions. Participants then trained EnGen of positive and negative emotional states, before training down-regulating emotions (not reported here). Further details of the procedure are reported in the *Supplemental Materials*.

Experimental procedure

Each trial (Figure S1) consisted of a Generation phase, where the target emotion (Positive, Negative, Neutral) was elicited, and a Modulation phase, where the elicited emotion was either Maintained or Regulated. Here we focus on the Maintain conditions while the Regulation component of the experiment will be reported elsewhere. In the Neutral condition, participants were instructed to actively maintain a neutral emotional state like the one previously induced in the training procedure.

The order of conditions was pseudo-randomized with no more than two condition repetitions, with 10 trials per condition. A trial (Figure S1) started with 1) a 4-6 second white fixation cross followed by 2) a 10 second Generation phase, in which subjects were shown a cue indicating which emotional state to generate (Red minus = Negative, Green plus = Positive, Blue zero = Neutral). 3) In the emotion generation conditions, a 5 second Modulation phase followed in which the instruction symbol remained the same (Maintain condition) or changed to a blue 0 indicating that subjects should down-regulate the emotional state they were in (Regulate condition; not reported). In the Neutral condition the participants were presented with a blue 0 for both Generation and Modulation phases (i.e. 15 seconds). After 5) a 5 second fixation cross, 6) a 5 second Visual Analogue Scale (VAS) ranging from “Extremely negative” via “Neutral” to “Extremely positive” (range: ± 250 from the neutral point (0)) was presented. For each trial, initial cursor position was jittered randomly (range: ± 100 points relative to 0). Responses were given using right-hand index and middle finger to move a slider using a two-button button box. Participants were instructed to report their affective state as it was at the moment of report. Stimuli were back-projected in the MRI scanner using a mirror setup. Eyesight was corrected using goggles where appropriate.

Assessing trait affectivity and emotion management styles

Participants completed an extensive package of questionnaires measuring a range of socio-affective and cognitive traits (Singer et al., 2016), including a range of measures of the tendency to experience positive and negative emotions (*Trait Affect*) and the tendency to use different emotion regulation and coping strategies (*Emotion Management Style*). *Trait Affect* was measured using questions regarding self-experienced positive and negative affect, including the Positive and Negative Affect Schedule (Krohne, Egloff, & Kohlmann, 1996), the Types of Positive Affect Scale (Gilbert et al., 2008), the Beck’s Depression Inventory II (Hautzinger, Keller, Kühner, & Beck, 2009), the trait form of the State-Trait Anxiety Inventory (Laux, Glanzmann, Schaffner, & Spielberger, 1981), the negative and positive affect

subscales of the NEO Five Factor Inventory (Borkenau & Ostendorf, 2008) and the negative affect and extraversion subscales of the Adult Temperament Questionnaire (Wiltink, Vogelsang, & Beutel, 2006). For *Emotion Management*, we included all scales measuring the tendencies to use different forms of coping or emotion regulation strategies, and the tendency to exercise self-control. This included the Cognitive Emotion Regulation Questionnaire (Loch, Hiller, & Witthöft, 2011); Brief COPE Inventory (Knoll, Rieckmann, & Schwarzer, 2005), Emotion Regulation of Self and Others (Niven, Totterdell, Stride, & Holman, 2011), and the effortful control subscale of the ATQ.

To have stable and comprehensive estimates of our trait measures of interest, we submitted the relevant scales to separate principal component analyses (PCAs; varimax rotation), reported in Figure 1C (*Supplemental Materials* for more detail on scale selection, analyses and interpretation of PCA components). Horn's parallel analysis (implemented in the *paran* package) was used to determine how many components to retain. Participant loadings on the resultant components was used subsequent analyses.

Results

Validation and operationalization of emotion generation efficacy

Post-trial subjective ratings were analyzed using *t* tests of the average reported affect in each condition (Figure 1A) in the final sample of 277. Relative to the Neutral (mean = 7.49, SD = 14.54) baseline condition, participants reported stronger affect in both Positive (mean = 85.31, SD = 53.00; paired *t* (276) = 27.77, *p* < 0.001) and Negative (mean = -74.98, SD = 54.76; paired *t* (276) = -28.42, *p* < 0.001) conditions.

Figure 1: Measures of emotion generation and affective styles. A) Distribution and descriptive statistics for the experimental conditions (Positive, Negative, and Neutral) and for the Composite Scores used in the main analyses. **B)** Component structure for questionnaire scales measuring trait affect (left) and emotion management (right). Scale loadings below $\pm .3$ are shown in white. **C)** Scatterplots and Pearson correlations between the unitary Trait Affect and the three Emotion Management components.

Taking the mean ratings participants made in each condition (Positive, Negative, Neutral; see Figure 1B) as an indicator of their generation abilities, we calculated composite efficacy scores relevant to the *buffering* and *simulation* hypotheses: As the *buffering hypothesis* highlights the role of valenced emotion generation abilities, we calculated a relative efficacy score as

$$\mu(Positive) - \mu(Negative)$$

Accordingly, a high positive score on this variable would correspond to high efficacy in generating positive relative to negative emotion and vice versa. Further, as the *simulation hypothesis* highlights valence-inspecific generation abilities, we calculated an average generation efficacy score:

$$\frac{\mu(Positive) + \mu(Negative)}{2} - abs(\mu(Neutral))$$

Thus, a high loading on this score corresponds to reporting higher affect in both Positive and Negative conditions relative to the intensity of affect (irrespective of valence) reported in the Neutral condition.

PCA of trait affect and emotion management style

For *Trait Affect*, parallel analysis combined with the scree method indicated the existence of a single component (Figure S2A) explaining 41% of variance in reports, with scales measuring positive trait affect loading negatively and scales measuring negative trait affect loading positively (Figure 1B). For ease of interpretation loadings were inverted for subsequent analyses, such that positive loadings reflect more trait positivity and vice versa.

For *Emotion management* styles, parallel analysis suggested three components (Figure S2B) explaining a total of 37% of variance in reports (see Figure 1B for loadings). Component 1 accounted for 14% variance, loading primarily on scales measuring the

tendency to cognitively transform negative emotional events. Component 2 accounted for 12% variance, with loadings primarily on scales measuring the tendency to blame oneself, ruminate, catastrophize and other maladaptive tendencies resulting in mood worsening. Component 3 accounted for 11% variance, loading primarily on items measuring the tendency to take an active, and problem-focused approach to emotional stressors by seeking support and employing active planning to mitigate stressors. We labeled these components as *Emotional*, *Maladaptive* and *Active*¹ styles of emotion management. Importantly, these components showed relationships with trait affect appropriate to our interpretation (see Figure 1C): Robust regression analyses (implemented with the *robust_base* R package) controlling for age and gender revealed that emotion management style explained a significant amount of variance (adjusted $R^2 = .5$, $F(3, 274) = 299$, $p < .0001$). Both *Emotion-focused* and *Active* management styles positively predicted trait affect ($b_{\text{Emotion-Focused}} = .30$, $t(271) = 6.34$, $p < .001$; $b_{\text{Active}} = .30$, $t(271) = 6.46$, $p < .001$) while *Maladaptive* management style negatively predicted trait affect ($b_{\text{Maladaptive}} = -.62$, $t(271) = -12.82$, $p < .001$). Thus, individual tendencies to use *Emotional* and *Active* management styles is associated with more positive and less negative affect, while *Maladaptive* usage is associated with less positive and more negative affect, validating our interpretation.

EnGen efficacy correlates with trait affect and emotion management styles

We next sought to investigate the relationship between individual differences in emotion generation efficacy and trait affect and emotion management styles. Using the R package *ppcor* (Kim, 2015), we calculated Pearson partial correlations between average and relative generation efficacy and loadings on the components described above, controlling for age, gender and the other efficacy measure (i.e. relative efficacy for the average efficacy

¹ While this component includes several techniques frequently associated with problem-focused coping (Lazarus & Folkman, 1984), we opt for the more general name *Active* here to highlight mix of proactive (planning), help-seeking (support-seeking) and active coping efforts in the current component, and to avoid drawing a false equivalence between the current component and the theoretical construct of problem-focused coping.

analyses and vice versa), and corrected for multiple comparisons using the Holm-Bonferroni method.

Relationship of Generation Efficacy and Affective Styles

Mediation modeling

Figure 2: Relationship between emotion generation and affective traits. A) Partial correlation between Average Generation ability and affective trait components, controlling for age, gender and Relative Generation Ability. **B)** Correlation between Relative Generation ability and affective trait components, controlling for age, gender, and Average Generation Ability. **C)** Mediation model tested for Average Generation efficacy, showing significant partial mediation of the relationship between Active emotion management style and Trait affect. **D)** Mediation model tested for Relative Generation efficacy, showing significant partial mediation of the relationship between Emotion-focused emotion management style and Trait affect. Parentheses in path coefficients denote standard deviations. * = $p < .05$, ** = $p < .01$, *** = $p < .001$, Holm- Bonferroni corrected

Scatterplots of these comparisons are reported in Figures 2 A and B. *Average Generation* ability was positively correlated with *Trait Affect* (partial $r(277) = .19$, $t = 3.24$, $p < .05$) and *Active* (partial $r(277) = .16$, $t = 2.65$, $p < .05$), but not *Maladaptive* (partial $r(277) = .06$, $t = .19$) or *Emotion-focused* (partial $r(277) = .01$, $t = .97$) emotion management styles. *Relative Generation* efficacy was positively correlated with *Trait Affect* (partial $r(277) = .18$, $t = 3.04$, $p < .05$), and *Emotion-focused* (partial $r(277) = .18$, $t = 3.08$, $p < .05$), but not *Maladaptive* (partial $r(277) = -.08$, $t = -1.30$) or *Active* (partial $r(277) = .09$, $t = 1.44$) emotion management styles.

Thus, these analyses demonstrate both common and differential trait associations for average and relative (positive versus negative) ability: Both measures are correlated with positive trait affect, even when controlling for the other, but they differ in their association with emotion management styles. This suggests that both measures relate to the impact of adaptive emotion management on trait affect, but that they do so by different pathways.

EnGen partially mediates relationship between emotion management and trait affect.

Our final analyses tested this possibility, seeking to establish whether emotion generation abilities mediated the relationship between emotion management and trait affect. Path coefficients were established using the *lavaan* R toolbox (Rosseel, 2012) using robust standard errors. Models were specified based on our correlation analyses (Figure 1C and Figure 2A), with separate models (Figure 2B) investigating whether *Average Generation* efficacy mediated the relationship between *Active* emotion management and *Trait Affect*, and whether *Relative Generation* efficacy mediated the relationship between *Emotion-focused* emotion management and *Trait Affect*. In each model the other efficacy score, age and gender were entered as covariates. If a mediated path is observed, we interpreted this as showing that EnGen abilities are part of the mechanism by which (adaptive) emotion management influences trait affect.

Mediation results are reported in Figure 2 B and C. For both *Average* and *Relative* models, paths largely replicated relationships reported above, showing significant direct paths between emotion management style and trait affect, and between emotion generation facets and both emotion management style and trait affect. Importantly, significant mediation was observed for both models (*Average*: $a*b$ path = .025, SE = .012, $z = 2.03$, $p < .05$; *Relative*: $a*b$ path = .025, SE = .012, $z = 1.99$, $p < .05$). However, as these effects did not survive correction for multiple comparisons, we used the *mediation* toolbox (Tingley, Yamamoto, Hirose, Keele, & Imai, 2014) to test the robustness of the indirect effects using nonparametric mediation analyses with bootstrapped confidence intervals (10000 samples). This revealed that both pathways were, indeed, significant, even after correcting for multiple comparisons using the Holm-Bonferroni method. Thus, our results suggest that average, but not valence-specific, generation ability is part of the mechanism by which *Active* emotion management improves *Trait Affect*. Conversely, *Relative Efficacy* partially mediated the relationship between *Emotion-focused* emotion management and *Trait Affect*.

Discussion

The objective of the current study was to test two competing hypotheses about how the capacity to endogenously generate (EnGen) emotional states might support emotion management and benefit affective mental health: 1) the *buffering hypothesis*, proposing that the ability to specifically generate positive emotion is important for facilitating emotion management skills aimed at positively altering ones hedonic state and 2) the *simulation hypothesis*, where the capacity to engage in the generation of emotional states irrespective of valence enables accurate prediction of affective consequences of future events, thereby increasing the efficacy of proactive and instrumental forms of emotion management. We tested these hypotheses using a minimally constrained paradigm where participants self-generated positive and negative emotion using endogenous sources of information, allowing us to operationalize two different facets of EnGen abilities: 1) *Average* ability, or the capacity

to generate emotional states irrespective of the valence, and 2) *Relative* ability, or the capacity to generate relatively more positive vs. negative emotion (or vice versa). This allowed us to measure individual differences in EnGen abilities in a representative sample of 277 participants, simultaneously assessing emotion management styles and trait affect, using a comprehensive questionnaire-based assessment.

We found that both the *Average* ability to generate positive and negative emotional states and *Relative* ability to generate positive versus negative emotion were positively correlated with trait affect. Both facets also correlated with adaptive forms of emotion management, but, importantly, different types: *Average* EnGen ability was exclusively associated with active, proactive, and instrumental forms of emotion management, while *Relative* EnGen ability was exclusively associated with trait usage of emotion-focused, internal forms of emotion management. These findings demonstrate that both *Average* and *Relative* EnGen abilities are positively linked to trait affect, and also to the expected types of emotion management. Further, we found that both average and relative EnGen abilities mediated the effect of their respective associated emotion management styles on trait affect. As such, our findings support both *buffering* and the *simulation* hypotheses and suggest a role of EnGen in facilitating the positive impact of a range of different adaptive emotion management styles on mental health.

Given the dearth of research on EnGen, the precise mechanisms by which these benefits accrue is a topic for future research, but the literature does provide some pointers for speculation. Clearest are the potential mechanisms by which the ability to generate relatively stronger positive than negative emotional state might affect trait affect. Assuming an even distribution of negative and positive exogenous and endogenous events in daily life, having the capacity to generate stronger positive states than negative will lead to an overall positive hedonic balance and thus, trait affect (Engen & Singer, 2015; Tugade & Fredrickson, 2004). For the simulation account, lack of empirical evidence makes the potential mechanisms more speculative, but one strong possibility is that they enable the embodied

episodic simulation of the emotional outcomes of future events, thereby enabling one to flexibly plan and adapt one's behavior to negative and facilitate positive emotional events (Bulley et al., 2017; Kashdan & Rottenberg, 2010; Miloyan et al., 2018; Miloyan & Suddendorf, 2015; Moulton & Kosslyn, 2009).

While our findings point to adaptive effects of EnGen, it should be noted that increased self-generated emotion is a hallmark of many affective disorders (Newman, Llera, Erickson, Przeworski, & Castonguay, 2013; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Exploring the precise relationship between adaptive and maladaptive EnGen and, in particular, understanding when EnGen goes wrong so as to provide effective intervention is an important topic for future research, with disruption in the ability to generate visual mental imagery in pathology emerging as a probably candidate mechanism (Hirsch & Holmes, 2007; Holmes, Blackwell, Burnett Heyes, Renner, & Raes, 2016). We have previously shown (Engen et al., 2018) that visual mental imagery is a very commonly employed and effective EnGen technique, suggesting that imagery deficits in pathology might lead a decreased ability to engage in EnGen. It is unclear whether this deficit is specific to positive imagery, suggesting decreased ability to engage in *buffering*, or EnGen overall, suggesting decreased *simulation* abilities. Future research should investigate this, as this could give greater insight both into the affective mechanisms that support pathology and give important pointers to how to design EnGen-focused interventions.

Limitations

A major limitation of the current findings is that data collection was performed in the context of an MRI scanning session, which, given its loudness and unfamiliarity, is probably a suboptimal context to engage in a challenging task like generating emotional states. It is possible that this deflated overall participant success, and, moreover, is likely to have made estimates of individual abilities noisier. This could be one explanation for the relative weakness of the mediation effect observed, possibly compounded by the open experimental

design. Studies need to be conducted to replicate the current findings in less demanding experimental settings, both in terms of context and specific task instructions. Indeed, the observation of significant effects despite these limitations could suggest an underestimation of the effect EnGen has on emotion management and trait affect.

Conclusion

We began this article citing Seneca, a central thinker in the Stoic tradition. The Stoics are known for holding that our suffering stems from endogenous sources, from our interpretations of what is and imaginations of what might be. The Stoics largely pivoted from this observation to the idea that all emotion should be suppressed and excised, supplanted by cold rationality – a notion that has suffused much of Western thought, and finds strong resonance in many Eastern intellectual traditions. Contrary to this, our findings suggest that our endogenous emotions appear to be helpful in supporting our emotion regulation efforts. Thus, while clearly a potential source of unproductive mental anguish, endogenous emotions might also be a potent ally, allowing us to employ our emotions instrumentally in order to facilitate emotional well-being, and, by doing so, support rationality itself.

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Supplemental Figures

Figure S1: Trial structure for the emotion generation experiment. Trials started with a jittered fixation cross, followed by a 10 second Generation phase, where a cue indicated whether participants should generate positive (green plus), negative (red minus) or neutral (blue zero) emotional states. A 5 second Modulation phase followed, where participants either maintained generation of the previously cued state or down-regulated their emotional states (not reported), followed by a 5 second fixation cross and a VAS rating of emotional intensity.

Figure S2: Results from Horn's parallel analyses. A) Parallel analysis indicates that 2 components should be retained (Adjusted Ev > 1), while scree criterion indicates that a single component should be retained above point of inflection. B) Parallel analysis indicates that 4 components should be retained (Adjusted Ev > 1), while scree criterion indicates that 3 components should be retained above point of inflection.

Supplemental Methods

Training procedure

Before scanning, participants underwent a supervised, automated training procedure. To ensure that participants had a shared understanding of the affective states they were requested to generate, they first underwent a multimodal affect induction procedure combining 1) emotional music, 2) affectively charged pictures and 3) verbal descriptions of bodily and psychological sensations associated with the different emotion states. This multimodal approach was adopted so that participants were not biased towards any particular information modality. The procedure aimed at inducing positive and negative emotional states of both high (e.g. happiness and fear) and low (e.g. tenderness and sadness) arousal. Additionally, subjects were induced into a neutral state by presenting them (unimodally) with emotionally neutral visual stimuli (neutral induction).

Participants were then presented with a list of four emotion generation modalities with short descriptions. Briefly, *semantic analysis* was described as a form of non-imagery based inner monologue, *episodic imagery* as imagining hypothetical or real situations or events of an emotional nature, *auditory imagery* as imagining emotionally evocative sounds, like music or the timbre of voices, while *bodily sensations* was specified as generating or amplifying bodily sensations associated with emotional states. The order of descriptions was counterbalanced. Participants were asked to select one or more of these modalities to use for the later generation task and were also given the option of using techniques or modalities that were not specified. If they did use a non-specified modality, they were asked to describe this in writing. Participants then chose which arousal level to generate (High vs. Low) separately for positive and negative emotion.

Three Generation trials identical to the experimental procedure followed in which participants generated positive, negative and neutral emotional states. After this, they were given the option to revise their initial selection of strategies in case they discovered the unsuitability of employed strategy and/or arousal level during training.

Participants also rehearsed how to down-regulate their generated emotional states. These part of the experiment does not figure in the current manuscript and will be reported in a future manuscript.

Questionnaire assessment of trait affect

As part of the ReSource Project ([/www.resource-project.org](http://www.resource-project.org)), participants completed a comprehensive package of questionnaires assessing a range of psychological traits, including the topic of the current paper: trait affect and emotion regulation and coping styles.

To generate a nuanced measure of trait affectivity we combined scales that where participants judge their own positive and negative affect. In the following the scales used and the rationale for their inclusion will be provided.

Positive and Negative Affect Schedule (PANAS; Krohne, Egloff, & Kohlmann, 1996)

The PANAS is a frequently used questionnaire that measures the tendency to experience positive and negative forms of affect. Importantly, studies indicate that the measure is stable over time (Watson, Clark, & Tellegen, 1988), suggesting that it measures differences in durable emotional traits.

The State-Trait Anxiety inventory (STAI; Laux, Glanzmann, Schaffner, & Spielberger, 1981)

Another frequently used measure, the STAI indicates to what degree an individual endorses feeling anxiety (i.e. a high-arousal negative emotional state) either in the moment (state) or on a regular basis (trait version), with the latter being the focus of the current investigation.

Beck's Depression Inventory II (BDI-II; Hautzinger, Keller, Kühner, & Beck, 2009)

The BDI-II is perhaps the most frequently used measure of depressive symptoms (i.e. a low-arousal negative state), both in clinical and research settings. While the scale

provided independent measures of both somatic and affective symptoms, we here combine these as we sought to use the BDI as a measure of overall trait affect.

The Types of Positive Affect Scale (TTPAS; Gilbert et al., 2008)

TTPAS is a relatively new scale that measures positive affect in a nuanced way, providing measures of high (active) and low (relaxation, compassionate warmth) arousal emotional states characteristic to different individuals that are typically not captured by traditional valence-focused measurements.

NEO-Five Factor Inventory: Positive and Negative subscales (NEO-FFI; Borkenau & Ostendorf, 2008)

The NEO-FFI is perhaps the predominant measure of personality traits used in psychological research. In addition to providing overall measurement of broad personality traits, the FFI includes a number of facets measuring specific personality characteristics (McCrae & Costa, 1992). Here we opted to focus on the subscales measuring the tendency to experience positive and negative affect rather than the main parent factors of extraversion and neuroticism. We elected to focus on subscales because the extraversion and neuroticism measure a wide range of behaviors not necessarily affective in nature.

Adult Temperament Questionnaire (ATQ; Wiltink, Vogelsang, & Beutel, 2006)

Finally, we included the negative affect and extraversion subscales from the ATQ. Emotional reactivity is a defining feature of temperament and can be thought of as being the physiological base of personality. The ATQ provides measures of the tendency to react to positive (Extraversion subscale) and negative (Negative Affect subscale) emotion, including both high and low arousal exemplars.

Assessment of coping styles

In addition to trait affect, we sought to measure individual differences in emotion management styles. To this end, we focused on scales measuring the tendency to use

different coping and emotion regulation strategies, as well as general measures of self-regulation tendencies.

Brief COPE (Knoll, Rieckmann, & Schwarzer, 2005)

The brief COPE inventory measures the degree to which an individual engages in different behaviors to cope with emotional stressors, and includes both adaptive and counterproductive coping strategies (e.g. self-blame or drug-use). Extensively used, the brief COPE has been shown to be associated with mental fortitude in the face of numerous challenges ranging from health issues to natural disasters. As such, the brief COPE provides a nuanced measure of the individual coping styles in applied settings. In the current study, all scales were included with the exception of the subscale measuring the tendency to find comfort in spiritual or religious practices, on account of the poor communality ($<.2$) of this subscale with the other scales.

Cognitive Emotion Regulation Questionnaire (CERQ; Loch, Hiller, & Witthöft, 2011)

Like the COPE, the CERQ measures the tendency to use different strategies in the face of negative emotional stressors. However, as the name suggests, it focuses on cognitive approaches to emotion management, i.e. those that involve thinking or attending to specific aspects of an emotional situation, thereby altering its emotional quality. The CERQ includes subscales measuring both adaptive (i.e. those that reduce or transform negative emotions) and dysfunctional (i.e. those that tend to intensify the negative emotion) strategies of varying cognitive complexity. Importantly, usage of these strategies have been shown to have an appropriate developmental trajectory, while the relative balance of adaptive and dysfunctional strategy use has been shown to be predictive of psychopathology (Garnefski & Kraaij, 2006).

Emotion Regulation of Self and Other scale (EROS; Niven, Totterdell, Stride, & Holman, 2011)

Unlike the COPE and CERQ, the EROS measures individual differences in the *goal* of emotion regulation (i.e. worsening or improving), and differentiates between

intrinsic and extrinsic means of regulation. As such, the EROS provides a more abstract measure of emotion management across numerous specific strategies and behaviors, and critically include a social dimension frequently overlooked in the literature at large.

Adult Temperament Questionnaire: Effortful Control subscale

Finally, we included the Effortful Control subscale of the ATQ. Effortful control is thought to be at the center of both cognitive and behavioral self-regulation, and has been shown to be inversely related to both negative affect, interpersonal problems, psychiatric symptoms and general distress (Wiltink et al., 2006). The effortful control subscale of the ATQ can be thought of as measuring the core dispositional ability to override emotional impulses and achieve behaviors in the face of e.g. inherent avoidance tendencies.

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