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Performance and Belief-Based Emotion Regulation Capacity and Tendency: Mapping Links With Cognitive Flexibility and Perceived Stress

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Cognitive reappraisal is among the most effective and well-studied emotion regulation strategies humans have at their disposal. Here, in 250 healthy adults across 2 preregistered studies, we examined whether reappraisal capacity (the ability to reappraise) and tendency (the propensity to reappraise) differentially relate to perceived stress. We also investigated whether cognitive flexibility, a skill thought to support reappraisal, accounted for associations between reappraisal capacity and tendency and perceived stress but found no evidence for this hypothesis. Both Studies 1 and 2 robustly showed that reappraisal tendency was associated with perceived stress, whereas a significant relationship between reappraisal capacity and perceived stress was only observed in Study 2. Further, Study 2 suggested that self-reported beliefs about one's emotion regulation capacity and tendency were predictive of wellbeing, whereas no such associations were observed with performance-based assessments of capacity and tendency. These data suggest that self-reported perceptions of reappraisal skills may be more predictive of wellbeing than actual reappraisal skills.

Keywords: cognitive reappraisal, emotion, emotion regulation, open science, wellbeing

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Cognitive reappraisal—reframing a stimulus so as to alter its emotional import—is one of the most widely studied emotion regulation strategies, in part because of its associations with numerous indicators of wellbeing and adjustment (Gross, 2015). Examples of such indicators include eating habits, decision making under uncertainty, mental health outcomes such as mood disorder symptomatology, and the measure tested in the present study—perceived stress (Denny & Ochsner, 2014; Giuliani & Pfeifer, 2015; Haines et al., 2016; Heilman, Crişan, Houser, Miclea, & Miu, 2010; Panno, Lauriola, & Figner, 2013; Zilverstand, Parvaz, & Goldstein, 2017). Although there are limitations to reappraisal (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Ford & Troy, 2019; Webb, Miles, & Sheeran, 2012), there is strong evidence to suggest it is a useful tool for maintaining both mental and physical health. And yet, the field currently lacks a mechanistic understanding of when and how reappraisal relates to wellbeing. Relatedly, inconsistent methodological choices in prior studies, along with unclear psychometric properties of commonly used measures, stand in the way of a mechanistic understanding of reappraisal's link to wellbeing and likely explain existing inconsistencies in the literature. The current report attempted to help resolve both issues of mechanism and psychometric understanding as they relate to cognitive reappraisal and wellbeing.

Toward a Mechanistic Understanding of Reappraisal and Wellbeing

The present study sought to provide a better mechanistic understanding of how reappraisal begets wellbeing—specifically, how reappraisal relates to a common disruptor of wellbeing, perceived stress—by answering three specific questions across two studies: (a) Does the relationship between reappraisal and wellbeing depend on how often people reappraise (i.e., their reappraisal *tendency*) or how effectively they reappraise (i.e., their reappraisal *capacity*)? (b) Does it matter how people actually use reappraisal, or merely how they believe they use it? (c) Does the link between reappraisal and wellbeing demand strong executive functioning? Here, we briefly introduce these open questions and subsequently review them in depth.

First, little is known about how individual differences in reappraisal capacity, one's ability to reappraise, and reappraisal tendency, how frequently one chooses to reappraise, independently affect wellbeing (McRae, 2013; Silvers & Guassi Moreira, 2019). This is partially because, to our knowledge, only four studies to

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date have assessed both tendency and capacity in the same individuals and linked them to wellbeing (Ford, Karnilowicz, & Mauss, 2017; McRae, Jacobs, Ray, John, & Gross, 2012; Troy, Ford, McRae, Zarolia, & Mauss, 2017; Troy, Wilhelm, Shallcross, & Mauss, 2010). The results of these studies have yielded somewhat inconsistent findings (correlations ranging from .01–.80, $M = 0.33$, $SD = .30$), making it unclear precisely how capacity and tendency independently relate to adjustment.

Second, and relatedly, it is poorly understood how beliefs about one's capacity and tendency to reappraise and one's actual capacity and tendency differentially relate to wellbeing. In other words, we do not know whether it matters more that someone thinks they are good at reappraising or use reappraisal frequently, or whether they actually are good at these things. This knowledge gap arises in part because different measurement modalities—performance (e.g., computerized tasks) and belief (e.g., global self-report inventories) measurements—are typically used to assess reappraisal capacity and tendency, respectively. Performance- and belief-based reappraisal capacity and tendency have rarely, if ever, been each measured in the same individuals, making it difficult to ascertain whether objective performance or one's self-reported beliefs about reappraisal capacity and tendency are more predictive of wellbeing.

Third, although a small number of studies have examined how different executive functions (e.g., cognitive flexibility) give rise to the ability to reappraise (McRae et al., 2012), none have assessed whether these executive functions account for reappraisal's associations with indicators of wellbeing like reduced perceived stress. Put differently, although reappraisal is thought to rely upon the engagement of executive functions—top down mental processes necessary for coordinating goal-directed behavior (Diamond, 2013)—it remains unknown whether these executive functions help explain ties between reappraisal and wellbeing. It is further unknown whether reappraisal's positive effects on wellbeing are driven by one executive function or are attributable to interactive effects between different executive functions.

Addressing these three outstanding questions has important implications for basic and applied affective science. A better mechanistic understanding of reappraisal promises to both refine formal theories of emotion and inform interventions whose goal is to improve wellbeing by virtue of strengthening emotion regulation skills.

Distinguishing Reappraisal Capacity From Tendency in Predicting Wellbeing

Some work relating reappraisal to wellbeing outcomes has focused on the *capacity* (sometimes referred to as *reappraisal ability*) to reappraise whereas other work has examined the *tendency* (sometimes referred to as *habitual reappraisal use*) to do so (Doré, Silvers, & Ochsner, 2016). These are, theoretically and empirically, distinct concepts (Doré et al., 2016; McRae, 2013; Troy et al., 2010; Silvers & Guassi Moreira, 2019): An individual may not reappraise effectively but still attempt to reappraise regularly, whereas another individual may be quite effective at reappraising yet rarely do so.

Given reappraisal's popularity as a research topic, surprisingly few studies have directly tested the extent to which reappraisal capacity and tendency are related to one another (Silvers & Guassi Moreira, 2019), let alone whether capacity and tendency are differentially associated with wellbeing. Among those that have examined links between reappraisal capacity and tendency, McRae and colleagues (2012) reported a modest, significant positive correlation ($r = .24$) whereas Troy et al. (2010) found no significant relationships between capacity and tendency (rs = .12, .21). Others (Ford et al., 2017; Troy et al., 2017) have found both significant and nonsignificant correlations between capacity and tendency (rs = .01–.80) that varied between different types of measurements (e.g., self-reports, daily diaries, laboratory tasks). To further complicate matters, much of the research in this area (e.g., McRae et al., 2012; Troy et al., 2010) has been conducted in samples characterized by narrow demographics (e.g., samples comprising only one sex, poor representation of racial/ethnic minorities, etc.), making it difficult to ascertain how results generalize to broader populations.

Given the fact that little work has assessed the association between reappraisal capacity and tendency, it is perhaps unsurprising that even less work has tested whether capacity and tendency are differentially associated with wellbeing. Several studies have shown that reappraisal tendency is positively related to measures of wellbeing such as better life satisfaction, social functioning, mental health, and dampened physiological responses during anger (Gross & John, 2003; John & Gross, 2004; Mauss, Cook, Cheng, & Gross, 2007). Far less research has examined the relationship between reappraisal capacity and wellbeing, although one study did find that capacity is inversely associated with depressive symptoms (Troy et al., 2010). To our knowledge, four studies have examined links between both reappraisal capacity and tendency and measures of wellbeing (e.g., Ford et al., 2017; McRae et al., 2012; Troy et al., 2010, 2017). These studies have yielded mixed results with regard to whether capacity and tendency both relate to wellbeing. One found that capacity and tendency share similar relationships with wellbeing (McRae et al., 2012), whereas another found that reappraisal tendency was robustly associated with wellbeing whereas capacity's association with wellbeing was inconsistent (Troy et al., 2017). A third study reported that capacity and tendency were uncorrelated, a nonsignificant main effect of capacity on wellbeing, a moderating role of capacity in predicting wellbeing, and did not report on the relationship between tendency and wellbeing (Troy et al., 2010). And yet, another study argued that there may be interactive effects between capacity and tendency (Ford et al., 2017). In sum, there is a possibility that the relationship between reappraisal and wellbeing outcomes differ for capacity and tendency, but additional research is needed to test this.

Parsing Beliefs About Reappraisal Skills From Actual Performance

The fact that research studies rarely examine reappraisal capacity and tendency in the same individuals is complicated by another methodological issue: Researchers also seldom take into consideration whether they are collecting performance-based or belief-based measures of capacity and tendency. The former refers to one's objective ability to regulate emotions via reappraisal (capacity) or their objective reappraisal frequency (tendency); the latter refers to how one perceives their ability to use reappraisal or their tendency to do so. Although the term *belief-based* can refer to many aspects of one's self-referential thoughts, here, we use the term to refer to perceptions of one's own emotion regulation skills (Fugate, Gouzoules, & Feldman Barrett, 2009), as opposed to higher-order, metabeliefs about the properties of emotions (Ford & Gross, 2018). Typically, as it relates to reappraisal research, researchers use global self-report methodologies to index belief-based reappraisal skills (e.g., Likert-scale questionnaires) and momentary self-report techniques to tap performance-based reappraisal skills (computerized tasks that rely on participant responses). For convenience, we assume our global and momentary self-report measures amount to adequate belief- and performance-based measures. We outline the limitations of this assumption in the Discussion section of the article.

Assessments of capacity and tendency tend to vary according to methodology (McRae, 2013). Capacity is most commonly assessed through computerized tasks that involve measuring how well one reappraises by comparing ratings of affect taken during reappraisal to affect during a meaningful baseline. By contrast, tendency is most commonly assessed with self-report questionnaires that measure how frequently one believes they reappraise. Recent reports examining performance and belief-based estimates of self-regulation skills such as impulse inhibition and discounting tendencies suggest that different modes of assessment can yield significantly different results in terms of psychometric properties (e.g., test–retest reliability) and the ability to predict real-world adjustment outcomes (e.g., obesity, drug use, etc.; Eisenberg et al., 2019; Enkavi et al., 2019). Even though belief-based measures of capacity (Troy et al., 2017, 2010) and performance-based measures of tendency (Hay, Sheppes, Gross, & Gruber, 2015; Scheibe, Sheppes, & Staudinger, 2015) exist, they are not as commonly used relative to their traditional counterparts. Moreover, no study to our knowledge has directly compared associations between capacity, tendency, and stress using multiple measurement modalities.

Executive Functions, Reappraisal, and Wellbeing

Dominant theoretical models posit that reappraisal relies on key executive functions that enable the formulation and deployment of a reappraisal (Buhle et al., 2014; Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner, Silvers, & Buhle, 2012). Having received accumulating support over the years (Ochsner et al., 2012), these theories highlight that reappraisal is akin to a machine that operates on interactions between many moving cognitive parts (i.e., executive functions). What is currently missing from the literature is the knowledge of *which* executive functions (i.e., parts) are most crucial for reappraisal to function and support wellbeing. The current investigation sought to examine whether two executive functions, working memory and cognitive flexibility, may partially explain reappraisal's association with wellbeing. As described below, we further hypothesized that cognitive flexibility might be more privileged over working memory.

Working Memory

Working memory is defined as the ability to temporarily store, recall, and manipulate information in memory (Baddeley, 2012). Several theoretical accounts posit that working memory is a multicomponent executive function that acts as a hub in a broader network with other executive functions (Baddeley, 2012; D'Esposito, 2007). Thus, we reasoned that working memory might help account for reappraisal's association with wellbeing in part because of its relationship with *other* executive functions. Working memory affects performance of other cognitive processes such as control of visual and spatial attention (Conway, Cowan, & Bunting, 2001; de Fockert, Rees, Frith, & Lavie, 2001), goal-directed planning (Kane et al., 2007), and inhibition (Kane & Engle, 2003). It follows that if working memory is compromised, then the ability to skillfully deploy other executive functions implicated in reappraisal might also be impacted. Consistent with this, prior work has suggested that individual differences in working memory track with cognitive reappraisal skills (Schmeichel, Volokhov, & Demaree, 2008; Scult, Knodt, Swartz, Brigidi, & Hariri, 2017).

Cognitive Flexibility

We define cognitive flexibility as the ability to dynamically update representations of a stimulus in accordance to external demands (Scott, 1962). Although fewer studies have examined links between reappraisal and cognitive flexibility than with working memory, there is some evidence that cognitive flexibility is also associated with reappraisal (McRae et al., 2012). We reason that cognitive flexibility is likely more crucial than working memory for supporting reappraisal and associated wellbeing for two main reasons. First, the very act of changing the way one thinks about a stimulus (i.e., reappraisal) is by definition an act of cognitive flexibility (Gross, 1998; Malooly, Genet, & Siemer, 2013). Studies suggest that because flexibility more closely mirrors the cognitive processes implicated with reappraisal, it may be more essential to cognitive reappraisal than working memory (Malooly et al., 2013; Siemer, Yoon, & Joormann, 2010). Second, though executive functions are broadly seen as being integral to ensuring wellbeing (e.g., Diamond, 2013; Insel, Morrow, Brewew, & Figueredo, 2006; Jacobson, Williford, & Pianta, 2011; Pennington & Ozonoff, 1996), cognitive flexibility appears to be more robustly related to markers of wellbeing than working memory is (Alexander, Hillier, Smith, Tivarus, & Beversdorf, 2007; Browning, Behrens, Jocham, O'Reilly, & Bishop, 2015).

For the reasons listed above, a key focus of our study was determining whether cognitive flexibility accounted for the relationship with reappraisal and wellbeing, over and above working memory. Although other studies have examined reappraisal, flexibility, and working memory in the same individual, our questions remain untested, given that prior work (a) has looked at reappraisal's relationships with working memory without controlling for cognitive flexibility or vice versa and (b) did not test whether either accounted for associations between reappraisal and wellbeing (McRae et al., 2012).

The Present Work

In Study 1 of the present article, we compare reappraisal capacity and tendency using historically dominant assessments (i.e., performance-based and belief-based, respectively). We then expand on this work in Study 2 by measuring reappraisal capacity and tendency with both traditional and nontraditional methods (i.e., using both belief- and performance-based measures for tendency and capacity). Across both studies, we use a combination of multiple regression and bootstrapping approaches to estimate the independent contributions that capacity and tendency exert on an important measure of wellbeing—perceived stress.

Our decision to use perceived stress as our primary outcome measure was motivated by three factors. First, stress is ubiquitous, with some estimating that nearly 60% of adults experience elevated levels of subjective stress (Wiegner, Hange, Björkelund, & Ahlborg, 2015). Second, stress is strongly associated with other serious health and psychological problems (Din-Dzietham, Nembhard, Collins, & Davis, 2004; Nielsen, Kristensen, Schnohr, & Grønbaek, 2008; Rod, Grønbaek, Schnohr, Prescott, & Kristensen, 2009). Lastly, perceived stress has been previously used as a measure of wellbeing in the reappraisal literature and we were thus able to build upon prior findings by using it in the present sample (Denny & Ochsner, 2014; Troy et al., 2017).

Prior to presenting the methods and results of Studies 1 and 2, it is useful to briefly discuss the psychometric properties of the measures used in these studies. As described in subsequent sections, the results of Study 1 and (to a lesser extent) Study 2 left us with several important methodological questions about our measures. In planning these studies, we selected measures that have been used extensively in the prior literature, but were never psychometrically validated. To this end, we performed supplemental analyses to examine surface-level psychometric properties of our measures. These were not meant to be definitive analyses but were instead intended to detect any glaring deficiencies in psychometric properties. Although these analyses are useful and relevant, they are beyond the immediate scope of our primary goals for this report. Therefore, we report them in great detail in the online supplemental materials. The main point to take away from these analyses is that all but one (our computationally based metric of cognitive flexibility being the only exception) of the measures range between fair (i.e., reasonable) to excellent in their psychometric properties.

Study 1: Testing Associations Between Reappraisal Capacity, Reappraisal Tendency, Cognitive Flexibility, And Executive Function

To investigate the research topics described above, we constructed a set of regression models. These models investigated whether greater reappraisal capacity or tendency predicted less perceived stress and then tested indirect effects to assess whether cognitive flexibility accounted for the association between reappraisal capacity or tendency and perceived stress. Notably, models involving indirect effects do not necessarily make assumptions of temporal causality between either facet of reappraisal, flexibility, and perceived stress. The aim is instead to understand whether the relationship between reappraisal and perceived stress is explained by flexibility (while controlling for working memory), agnostic to the direction of the causal arrows. We preregistered all aspects of our study, including hypotheses, on the Open Science Framework (osf.io/f5aak). As noted below, our confirmatory hypotheses centered on cognitive flexibility, whereas our exploratory analyses centered on contrasting reappraisal capacity and tendency.

Our confirmatory hypotheses are as follows.[1] Note that we controlled for working memory while testing these hypotheses, as indicated in our preregistration:

> *Hypothesis 1:* Cognitive flexibility will statistically account for the association between cognitive reappraisal capacity and perceived stress.
>
> *Hypothesis 2:* Cognitive flexibility will statistically account for the association between cognitive reappraisal tendency and perceived stress.

Our post hoc, exploratory analyses are as follows:

1. We first tested the effects of reappraisal capacity and tendency on perceived stress while controlling for one another.
2. We evaluated additional models that reflect alternative theoretical relationships (e.g., moderating vs. indirect relationships) between capacity, tendency, flexibility, and perceived stress.
3. We used bootstrapping to compare model fits of associations of reappraisal capacity and perceived with associations of reappraisal tendency and perceived stress.

Method

Participants. We recruited participants from the undergraduate psychology subject pool at the University of California, Los Angeles. As part of the study's preregistration, we set an a priori sample size of 125 subjects. This number was determined by considering the sample sizes of prior work and logistical constraints surrounding the current study. No formal power analysis was performed. It follows that our data collection stoppage rule was to terminate data collection upon running 125 subjects. Notably, our sample size is significantly larger than several prior studies with similar research questions (e.g., McRae et al., 2012). Our final sample of 125[2] undergraduates included 94 females (75.2%) and had a mean age of 21.49 years (*SD* = 2.5; range = 19–39). Racially, 36.8% of our participants were Asian, 32% were Caucasian, 5.6% were mixed race, 0.8% were African American, 0.8% were Native American, 14.4% identified as "Other," and 9.6% declined to respond. Ethnically, 19.2% of our sample identified as Latinx. Though not explicit in our study protocol, English proficiency was a de facto requirement. Written consent was obtained for all participants in accordance with policies of the UCLA Institutional Review Board. Data, materials, and code are publicly available on the OSF (osf.io/97kqy).

Procedure. Participants responded to a study advertised on the subject pool website as investigating the link between emotions and decision making. Participants completed three computerized experimental measures (assessing reappraisal capacity, cognitive flexibility and working memory), a survey with self-report mea-

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[1] The pre-registration and earlier versions of this manuscript originally described cognitive flexibility as *mediating* the association between capacity and tendency. Although our analyses remain the same, we have changed the language here to reflect the fact that we did not want to mislead readers into thinking we were making assumptions of temporal causality. Mediation models can still be informative in absence of these assumptions.

[2] Two participants failed to properly complete a measure of working memory (described later). Sample sizes for analyses that use this measure are thus 123.

sures of interest (including reappraisal tendency and perceived stress), and other exploratory measures. Participants were greeted and consented upon arrival, completed the computerized measures, and then filled out the survey. All measures are detailed in our preregistration document, hosted on the OSF. Computerized measures reported in this study were programmed in PsychoPy (Version 1.82.01; Peirce, 2007). Another measure was collected to answer a set of orthogonal research questions to be addressed in a separate article. The order of computerized measures was counterbalanced across subjects. Participants were trained in accordance with well-validated procedures (McRae et al., 2012; Silvers et al., 2012) by an experimenter and were not allowed to proceed until demonstrating they properly understood the task. The experimenter remained present in the room during the experimental session to answer questions and unobtrusively monitor participants to ensure they remained focused. The computerized measures ranged between approximately 4–12 min in duration. Sessions typically took between 45 and 70 min to complete, including consenting participants, training them on how to complete the tasks, and completing questionnaire measures.

Measures.

Reappraisal capacity. Reappraisal (performance-based) capacity was assessed using a computerized paradigm adapted from prior reappraisal protocols (McRae et al., 2012; Silvers et al., 2012; Silvers, Weber, Wager, & Ochsner, 2015). During the task, participants were presented with a series of neutral or negatively valenced images drawn from the Open Affective Standardized Image Set (Kurdi, Lozano, & Banaji, 2017). Neutral images included depictions of inanimate objects, landscapes, and mundane social interaction. Negative images included depictions of injuries, destruction, animal waste, and arguments. Each image was associated with a *Look* or *Decrease* cue. *Look* cues instructed participants to passively view the stimuli. *Decrease* (reappraise) cues were only paired with negative images, and meant participants were to reinterpret the stimulus in a way that helped decrease their emotional response to it. Each image was only shown once and paired with either the Look or Decrease cue, helping reduce the likelihood of habituation. Decrease and Look–Negative images were matched on valence.

After the stimulus was displayed, participants were prompted to rate their negative affect along a 5-point Likert scale (1 = *Neutral*, 5 = *Very Negative*). Participants were trained extensively to reappraise by thinking about how the possible antecedents, outcomes, or reality of the event in the picture could actually be different than what was ostensibly depicted (Silvers et al., 2015). Individuals were guided through a series of PowerPoint slides giving them step-by-step instructions on what the task would look like and what they were to do at each part of a trial (e.g., cue, stim, rate). Afterward, participants completed a brief practice session in which the experimenter walked them through two trials and they then completed four trials on their own. To avoid confounds attributable to potential demand characteristics, participants were made aware that it was possible to try to decrease negative emotion and still feel very negative.

Each trial could last a maximum of 12 s—cues were shown for 2 s, stimuli for 7 s, and the response scale was displayed for 3 s at most (terminated by user response; Mean response time = 888.96 ms, *SD* = 316.51 ms). There were 20 trials for each condition (Look Negative, Look Neutral, Decrease Negative), totaling 60 trials for the entire task. Reappraisal capacity, defined as the percent change in negative affect between the average affect ratings in the Look Negative and Decrease Negative conditions, was calculated as follows:

$$\text{Reappraisal Capacity} = ([\text{Look Negative} - \text{Decrease Negative}]/\text{Look Negative} \times 100)$$

A greater score indicates better reappraisal capacity. As noted above, performance-based capacity was used for this study so as to be consistent with historical norms. Study 2 employed multiple measures of capacity.

Reappraisal tendency. Reappraisal tendency (belief-based) was assessed via self-report on the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). The ERQ taps two emotion regulation strategies, cognitive reappraisal and expressive suppression. We administered the entire measure to avoid impinging upon its validity but focused analyses on the six-item reappraisal subscale of the ERQ, which measures habitual use of reappraisal for regulating emotions in everyday life. The reappraisal subscale of the ERQ is an appropriate measure of tendency for two major reasons. First, although some of the items indirectly allude to reappraisal success, it is arguably more geared toward assessing frequency of reappraisal use because the wording is more focused on what individuals do instead of how well they do it. Second, an overwhelming number of prior studies have used it to measure tendency (McRae et al., 2012; Troy et al., 2010). Respondents are asked to rate the extent to which they agree with a series of statements on a seven-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree*). Sample items include "I control my emotions by changing the way I think about the situation I'm in" and "When I'm faced with a stressful situation, I make myself think about it in a way that helps me stay calm." Items of the reappraisal subscale were averaged into a single mean score, with greater scores indicate greater reappraisal tendency. The measure displayed good reliability (α = .83). As noted above, belief-based tendency was used for this study so as to be consistent with historical norms. Study 2 utilized multiple assessments of tendency.

Perceived stress. Perceived stress was measured using the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983). The scale measures the degree to which individuals appraise general life events as being subjectively stressful. Participants are presented with a series of 14 items related to thoughts and feelings people have when stressed. Participants are then asked to indicate, along a 5-point Likert scale, how often they have experienced each of the items in the past month (1 = *never*, 3 = *sometimes*, 5 = *very often*). Sample items include "How often have you found that you could not cope with all the things you had to do?" and "How often have you been upset because of something that happened unexpectedly?" Items were reverse coded when appropriate and averaged to yield a single score. Greater scores indicate greater perceived stress. As noted above, a self-reported questionnaire measure of perceived stress was used for this study while Study 2 utilized multiple measures of perceived stress. The measure was found to have good reliability in our sample (α = .85).

Cognitive flexibility. We measured cognitive flexibility by administering a computerized probabilistic reversal learning measure and then implementing a computational reinforcement learning model to obtain a parameter estimate that would serve as our metric of cognitive flexibility.

First, participants were asked to complete a canonical, two-choice probabilistic reversal learning task (e.g., den Ouden et al., 2013; Hanson et al., 2017). Participants were told they would see a blue and yellow slot machine on every trial and that the slot machines would differ in their likelihood of paying out. Participants were instructed to pick the machine that paid out the most often. Importantly, participants were notified that the likelihood of paying out for a given machine could change throughout the task so they had to keep track of the machine that was paying out the most often and select it. The payout likelihood of a given machine switched between .7 and .3 approximately every 35 trials (though participants were not made aware of this). Participants completed 138 trials in total. The pay-outs from the slot machines in this task were hypothetical; participants did not receive actual money for completing the task.

To obtain a metric of cognitive flexibility from these data, we implemented a simple computational reinforcement learning model. Specifically, a Rescorla-Wagner model (Rescorla & Wagner, 1972) was used to model how participants update the value of stimuli. The critical parameter of this model is typically referred to as the learning rate (α) and is traditionally seen as a constant value that weighs the extent to which a prediction error is incorporated when updating the subjective value of a given stimulus. Here we interpret alpha as a measure of cognitive flexibility, in line with past research (Hauser, Iannaccone, Walitza, Brandeis, & Brem, 2015). For one to learn during the task, a participant must be aware that value contingencies are changing and revise their beliefs accordingly—similarly to how one must revise their interpretation of an affective stimulus during reappraisal. Using a probabilistic reversal learning task in conjunction with this computational model has several advantages. First, other approaches, like a global/local task (Hedden & Gabrieli, 2010), tend to collapse performance over the course an entire task or questionnaire, essentially ignoring valuable heterogeneity across task performance. Other measures of flexibility rely on subjective scoring of participant responses (e.g., unusual use tasks). By contrast, our approach is data-driven, readily incorporates within-task heterogeneity, and results in an index that is theoretically more sensitive to individual differences than conventional measures (Hauser et al., 2015). Lastly, and most crucially, using the RW equation allowed us to characterize a psychological construct using a computational approach, reducing ambiguity in the form of a mathematical definition, providing a clearer operationalization of what we intend to study, and being more generative and specific with respect to underlying mechanisms.

Working memory. Because cognitive reappraisal is thought to comprise several different executive functions (Ochsner et al., 2012), it was necessary to control for working memory to test whether cognitive flexibility uniquely accounted for the association between reappraisal and perceived stress. To this end, we administered a standard 2-back working memory task. Participants were shown a series of letters, each one at a time, and were asked to indicate whether the current letter is the same or different as the one presented two trials before it. Each letter was presented for 2,000 ms, separated by a 750-ms fixation cross. There were 100 trials total, 30 of which were target trials (i.e., *same*) and 70 were nontarget trials (i.e., *different*). To create a summary index from the data, we calculated d' scores based on normalized rates of hits (correctly remembering a letter matched the one shown two trials earlier) and false alarms (incorrectly indicating a letter matched one shown two trials earlier; Stanislaw & Todorov, 1999).

Analysis plan. We tested our hypotheses by running two sets of preregistered analyses—each set included a different facet of cognitive reappraisal as a predictor (i.e., capacity or tendency). First, we conducted two simple linear regressions in which perceived stress was the dependent variable regressed on capacity or tendency. Second, we ran two bias-corrected bootstrapped path analyses,[3] as specified by Preacher and Hayes (2008), to determine whether cognitive flexibility (indexed by α from the RW model) accounted for covariance between capacity and perceived stress, and tendency and perceived stress (model number 4 in the SPSS PROCESS macro). We specifically chose to use bias-corrected bootstrapped analyses because of their distinct power advantages—they are equipped with better power to detect a range of effect sizes than other alternatives and thus require only relatively modest sample sizes (with respect to other methods; Fritz & Mackinnon, 2007). Third, we reran the path analyses, but this time residualized our cognitive flexibility variable on d' scores of working memory. In addition to reporting traditional p values, we also report confidence intervals for all results. All analyses were conducted on a Windows 10 machine with IBM SPSS Statistics (Version 24).

We note here that the path analyses we employ are frequently referred to as mediation. We have intentionally refrained from using that particular term to avoid confusion about temporal assumptions of causality. Our aim is instead to test whether cognitive flexibility statistically accounts for the covariance in a set of given association *without* making temporally causal assumptions (Thoemmes, 2015).

Results

Overview. The results are organized as follows. We first summarize results of diagnostic analyses (fully described in the online supplemental materials) testing the basic Gauss-Markov assumptions of ordinary least squares regression and then describe basic descriptive statistics of the sample. We then report results of confirmatory (i.e., preregistered) analyses and conclude with a description of exploratory (i.e., post hoc, follow-up) results.

Diagnostics and basic descriptive statistics.

Regression diagnostics. We ran a series of diagnostics to verify whether our data violated the Gauss-Markov assumptions for linear regression. Procedures and results are detailed in depth in the online supplemental materials. Briefly, we generally found no major violations of the Gauss-Markov assumptions. Although there were slight violations of homoscedasticity, we note that linear regressions are generally robust to such violations (Cohen, Cohen, West, & Aiken, 2013). In consideration of the slight biases observed, we report 99%, bootstrapped confidence intervals (10,000 iterations).

Bivariate correlations and descriptive statistics. Descriptive statistics and bivariate correlations between all study variables are

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[3] We ran the same analyses for working memory, our control executive function, at the suggestion of a previous reviewer. Said analyses yielded null results.

displayed in Table 1. Notably, reappraisal capacity and reappraisal tendency were not correlated, $r(123) = .01$, 99% CI [−.22, .23], $p > .250$. Tendency and perceived stress evinced a medium-sized, significant correlation, $r(123) = -.30$, 99% CI [−.49, −.06], $p = .001$. Cognitive flexibility exhibited a modest, albeit nonsignificant, correlation with reappraisal tendency, $r(123) = -.16$, 99% CI [−.38, .06], $p = .070$, and displayed a similar relationship with reappraisal capacity, $r(123) = .13$, 99% CI [−.10, .35], $p = .159$. Working memory was significantly correlated with capacity, $r(121) = .20$, 99% CI [−.03, .41], $p = .029$, but not tendency, $r(121) = .08$, 99% CI [−.15, .30]. Lastly, we ran a one-sample t test on scores of capacity to check if participants were engaging in reappraisal as directed. The mean capacity value of 29.11 was highly significant relative to a null value of zero, $t(124) = 20.41$, $p < .001$, providing evidence that our task tapped cognitive reappraisal capacity in the current sample. Mean scores of tendency and perceived stress were 4.86 ($SD = 1.10$) and 3.05 ($SD = .56$), respectively (see Table 1).

Confirmatory results.

Relationship between reappraisal capacity, cognitive flexibility, and perceived stress. First, we conducted a simple linear regression in which perceived stress was regressed on scores of reappraisal capacity. The results of this analysis failed to reject the null hypothesis ($B = .002$, $SE = .003$, 99% CI [−.005, .009], $p > .250$, $R^2 = .002$). Next, we ran path analyses in which capacity was entered as the predictor, perceived stress as the outcome, and cognitive flexibility as accounting for the relationship between the two. The point estimate of the indirect effect of X on Y (i.e., c–c') was found to be −.0005 (bootstrapped $SE = .0006$, 99% CI [−.0035, .0006], 10,000 iterations). Because the confidence interval included 0, we cannot conclude a statistically significant indirect effect. Lastly, we reran the analysis with cognitive flexibility scores residualized on working memory, allowing us to control for the latter. The point estimate of the indirect effect was still not significant (Indirect Effect = −.0003, bootstrapped $SE = .0005$, 99% CI [−.0029, .0006]).

Relationship between reappraisal tendency, cognitive flexibility and perceived stress. Similar to the analyses described above, we began by regressing perceived stress on scores of reappraisal tendency. Consistent with our hypothesis, greater reappraisal tendency was related to lower self-reported perceived stress ($B = -.151$, $SE = .043$, 99% CI [−.261, −.035], $p < .001$, $R^2 = .089$). Subsequent path analyses revealed that cognitive flexibility did not statistically account for the association between tendency and perceived stress (Indirect Effect = .0113, bootstrapped $SE = .0107$, 99% CI [−.0058, .0581], 10,000 iterations), even when controlling for working memory (Indirect Effect = .0117, bootstrapped $SE = .0114$, 99% CI [−.0075, .0610]).

Table 1
Descriptive Statistics and Bootstrapped Bivariate Correlations Between All Study Variables

Variable	*M* (*SD*)	1	2	3	4	5
1. Capacity	29.11 (15.95)	1				
2. Tendency	4.86 (1.10)	.01	1			
3. Perceived stress	3.05 (0.56)	.05	−.30*	1		
4. Cognitive flexibility	0.57 (0.32)	.13	−.16	−.09	1	
5. Working memory	3.42 (1.32)	.20*	.08	−.10	.13	1

Note. Capacity refers to reappraisal capacity and represents percent change in negative affect when reappraising and passively viewing negative stimuli; Tendency refers to mean scores from the reappraisal subscale of the ERQ; Cognitive flexibility refers to the computationally estimated alpha parameter; Working memory refers to d' scores calculated from our n-back task (2-back design). Assessment of capacity was performance-based; assessments of tendency and perceived stress were belief-based.
* $p < .05$.

Exploratory results. After preregistration, data collection, initial stages of data analysis, and correspondence with colleagues, we were motivated to conduct a set of post hoc, exploratory analyses.

Does tendency predict perceived stress above and beyond capacity? First, even though tendency and capacity were not significantly correlated, we still thought it necessary to test whether tendency was still associated with perceived stress, over and above the effect of capacity. A multiple regression analysis confirmed that this was the case (capacity: $B = .002$, $SE = .003$, 99% CI [−.005, .009], $p > .250$; tendency: $B = -.151$, $SE = .043$, 99% CI [−.262, −.036], $p < .001$, adjusted $R^2 = .077$).

Considering alternative models. Next, we considered that we may have specified a theoretically incorrect model—perhaps cognitive flexibility *moderates* the relationship between reappraisal and perceived stress. We ran two follow-up moderation analyses to determine whether cognitive flexibility—residualized on working memory—moderated links between reappraisal tendency and capacity. Both analyses yielded null results (Model 1, Tendency × Flexibility interaction term $B = -.051$, $SE = .047$, $p > .250$; Model 2, Capacity × Flexibility interaction term $B = .034$, $SE = .052$, $p > .250$). Based on prior literature (Ford et al., 2017), we also tested whether capacity and tendency have interactive effects on perceived stress with a moderation analysis in which perceived stress was predicted from capacity, tendency, and a Capacity × Tendency interaction term. The interaction term was not significant ($B = -.037$, $SE = .050$, $p > .250$).

Comparing model fits between capacity and tendency. The final follow-up analysis we conducted was to determine whether the model predicting perceived stress from tendency was significantly better fitting than the one predicting perceived stress from capacity. Descriptively, the former has a higher R^2 value than the latter (.089 vs. .002). However, it was unclear whether this value is statistically significant. Because the models are not nested, we could not conduct a formal model comparison by traditional means. In light of this, we opted to a use a bootstrapping approach, implemented in R (Version 3.3.2). We sampled from our own data 50,000 times, with replacement, fitting a perceived stress-tendency model and a perceived stress-capacity model each iteration and computing the difference in their R^2 values. We used the 50,000 scores of differences in R^2 values as an approximation of the sampling distribution. Constructing a 95% confidence around the distribution revealed that it did not include zero (95% CI [.005, .158]), indicating that the perceived stress-tendency model is significantly better fitting than the perceived stress-capacity model.

Interim Discussion

The first key finding from Study 1 indicates that the tendency to engage in reappraisal more frequently is associated with significantly lower perceived stress, although there was no such evidence for a relationship between cognitive reappraisal capacity and perceived stress. Events can often be perceived as stressful when individuals feel they lack control over them (Averill, 1973; Thoits, 2010; Thompson, 1981). For this reason, greater reappraisal tendency may be related to less perceived stress because it imbues individuals with a sense of control over their circumstances. We also found that cognitive flexibility does not account for the association between either facet of reappraisal (capacity or tendency) and perceived stress. This null funding could mean that cognitive flexibility is simply not important for reappraisal, or that it does not have implications for wellbeing. However, given that our study was the first reappraisal study to use reinforcement learning models to derive an index of cognitive flexibility, it is also plausible that this measure of cognitive flexibility fails to appropriately assess cognitive flexibility as it is used in the context of cognitive reappraisal. Another possibility is that reappraisal is an emergent system—a system that is greater than the sum of its parts and no one single mechanistic feature is any more privileged than the others. One final explanation for Study 1's findings is that we tested the association between beliefs about reappraisal tendency and beliefs about perceived stress, compared to performance related to reappraisal capacity and beliefs about perceived stress. This implies the possibility that the constructs studied here only show relations within belief- or performance-based categories for substantive or methodological (e.g., method variance) reasons. For this reason, Study 2 sought to replicate and extend the findings of Study 1 using multiple measures of reappraisal capacity and tendency as well as perceived stress.

Study 2: Replication and Understanding Differences Between Beliefs and Performance

We aimed to accomplish two goals in Study 2. First, we set out to replicate Study 1 results (confirmatory and exploratory) to bolster confidence in the robustness of our initial findings. To recapitulate, we broadly found that tendency was both a significant and better predictor of perceived stress than capacity while also showing that cognitive flexibility evinced an indirect effect on either relationship. Second, we sought to address Study 1's aforementioned limitations by (a) assessing performance- and belief-based metrics of capacity, tendency, and perceived stress while (b) collecting an additional, more traditional measure of cognitive flexibility. By doing so, we hoped to clarify whether reappraisal tendency is truly a better predictor of perceived stress than reappraisal capacity, or whether self-report measures about reappraisal, regardless of whether its related to tendency or capacity, are more predictive of perceived stress than performance-based measures. Additionally, we sought to test whether the null (or negligibly small) indirect effect of cognitive flexibility on perceived stress observed in Study 1 was idiosyncratic to the specific measure of cognitive flexibility used. Our hypotheses for Study 2 were the same as Study 1, tested under novel conditions (e.g., with additional index of cognitive flexibility, etc.), and all hypotheses were again preregistered (osf.io/4rm6e). As in Study 1, we conducted follow-up exploratory analyses after seeing results for this study.

Method

Participants. We recruited participants from the at-large community at the University of California, Los Angeles by posting flyers, tapping mailing lists, and encouraging word of mouth referrals. As part of Study 2's preregistration, we set an a priori sample size of 125[4] subjects to be consistent with Study 1. Our final sample included 88 females (70.4%) and had a mean age of 21.17 years (*SD* = 3.1, range = 18–37). In terms of race, 36.89% identified as Asian, 34.43% identified as Caucasian, 7.4% identified as African American, 0.8% identified as American Indian/Alaskan Native, 0% identified as Native Hawaiian or Other Pacific Islander, 8.2% were mixed race, 5.7% identified as "Other," and 6.5% declined to respond. In terms of ethnicity, 23.8% of the sample identified as Latinx. As in Study 1, English proficiency was a de facto requirement because all study communication was performed in English. Written consent was obtained for all participants in accordance with the policies of the UCLA Institutional Review Board. Data, materials, and code for Study 2 are publicly available on the OSF (osf.io/nmyp4).

Procedure. Study 2 occurred in three phases. First, participants scheduled an initial laboratory visit to consent to participate in the study and receive instruction on how to complete daily surveys that were used as a performance-based measure of perceived stress (see subsequent text). Second, participants completed a daily survey period wherein they were emailed surveys in the evening for seven consecutive days. Third, 1–3 days following completion of the survey period, participants returned to the lab to complete the rest of the study measures. This final lab session was similar to that in Study 1. Participants completed computerized measures (assessing performance-based reappraisal capacity, performance-based reappraisal tendency, two separate measures of cognitive flexibility, and working memory) and self-report measures (self-reported belief-based reappraisal capacity, self-reported belief-based reappraisal tendency, self-reported belief-based perceived stress, and other exploratory measures). A subset of the exploratory self-report measures administered in Study 1 were also collected in Study 2 (as before, the preregistration discloses all measures that were collected). The order of computerized measures was counterbalanced across subjects. Training procedures, nonintrusive monitoring, and task/session durations for this final lab session were similar to Study 1.

Measures.

Performance-based reappraisal capacity. Performance-based reappraisal capacity was assessed using the same instructions, paradigm, and estimation procedure as described in Study 1.

Belief-based reappraisal capacity. Belief-based reappraisal capacity was operationalized as scores from a modified version of the ERQ (sometimes referred to as a *Reappraisal Capability* or *Cognitive Reappraisal Ability* self-report measure; we refer to it as the *ERQ Capacity* measure; Troy et al., 2017). The eight-item measure was adapted from the original ERQ. Specifically, the original ERQ items, which ask about reappraisal frequency, were adapted to ask one's *ability* to reappraise (sample items: "When I really want to, I am very capable of changing the way I am thinking about a situation that is likely to make me feel strong emotions" and "When I really want to, I am very capable of controlling my emotions by changing the way I think about the

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[4] Three participants dropped out of the study following the daily survey period, and a handful of participants were excluded from analyses for noncompliance. Sample sizes thus varied between 119 and 125.

situation I'm in"). As with the original ERQ, all responses were made a seven-point scale (1 = *strongly disagree*, 7 = *strongly agree*), and items were averaged together to yield a single value of belief-based capacity ($\alpha = .90$).

Performance-based reappraisal tendency. We used a computerized Emotion Regulation Choice task (ERC; Sheppes, Scheibe, Suri, & Gross, 2011) to derive a performance-based metric of reappraisal tendency. Each trial on the task is comprised of four phases: stimulus preview, decision, decision follow-through, and self-reported affect rating. Participants are first presented with a brief (750 ms) preview of the stimulus without any accompanying instruction. Afterward, the image disappeared and they were shown a decision screen with a centered fixation cross and "CHOOSE" shown at the top of the screen. Participants had 15,000 ms to decide, via button press, whether to reappraise via reinterpretation (*decrease*; e.g., imagining the antecedents of the image were misleading as depicted in the image) or passively observe the image (*look*). If no choice was made, *look* was chosen by default. Next, the image was redisplayed for 5,000 ms, accompanied by text ("LOOK" or "DECREASE") at the top of the screen to ensure participants were reminded of their choice. Finally, participants rated their affect on a 5-point Likert scale identical to the one from the task assessing performance-based capacity (3,000 ms). A 1,500 ms intertrial interval (ITI; with fixation cross) was sandwiched between trials. Design features of this task (e.g., timing) are broadly consistent with prior work (Hay et al., 2015; Martins, Sheppes, Gross, & Mather, 2018; Scheibe et al., 2015).

All stimuli for this task were negatively valenced and drawn from both Open Affective Standardized Image Set (OASIS) and the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) stimulus set. The task consisted of 40 trials. One participant declined to complete the ERC task, three participants dropped out after the daily survey period, and two did not properly comply with instructions, meaning the final sample size for ERC task data was $N = 119$. As a manipulation check, we used random coefficient regression (which accounts for repeated measures nested within individuals) to determine whether choices to reappraise were associated with decrease negative affect ($\text{Affect}_{ij} = \gamma_{00} + \gamma_{10}(\text{Decision}_{ij}) + u_{0j} + u_{1j} + e_{ij}$). Indeed, the fixed effect of choosing to reappraise indicated a significant, expected decrease in negative affect ($\gamma_{10} = -0.721$, $SE = .099$, $p < .001$). We obtained subject-specific estimates of performance-based tendency by using empirical Bayes estimates from a random coefficient regression model. Larger values indicated a greater propensity to reappraise. Our preregistered use of this technique theoretically allows for better estimation of performance-based tendency as it not only uses information from each individual, but also incorporates information about the rest of the sample into the estimate. Specific details on this estimation procedure can be accessed in the online supplemental materials.

Belief-based reappraisal tendency. Belief-based reappraisal tendency was measured the same way as it was in Study 1, via the original ERQ ($\alpha = .84$).

Performance-based perceived stress. A metric of performance-based stress was computed using the aforementioned daily surveys. During the daily survey period, participants were required to answer a 1-item surveys tapping their perceived stress during the day. The survey required participants to use a 5-point Likert scale (1 = *not at all stressed*, 2 = *slightly stressed*, 3 = *moderately stressed*, 4 = *very stressed*, 5 = *extremely stressed*) to answer a single question about that day's subjective stress ("Overall, how stressed do you feel today?") The daily survey period lasted for seven consecutive evenings. Participants were emailed their nightly survey at 7 p.m. (sent via Qualtrics), received a text message reminder at 8 p.m. (sent via ohdontforget.com), and were instructed to complete the item anytime between 7 p.m. and when they went to bed. Every participant except one completed at least five nightly surveys (only four surveys were recorded for one participant because of a technical error).

We obtained subject-specific estimates of performance-based perceived stress by using empirical Bayes estimates from a random coefficient regression model. Larger values indicated greater performance-based perceived stress. As noted in the preceding section, this technique theoretically allows for better estimation of performance-based tendency as it not only uses information from each individual, but also incorporates information about the rest of the sample into the estimate. Specific details on this estimation procedure can be accessed in the online supplemental materials. We note that this composite of perceived stress is not necessarily performance-based in the same way that the performance-based reappraisal measures are, but it is nevertheless more similar to a performance-based assessment insofar that it is not as susceptible to response or memory biases in the same way that completing a one-shot, summary questionnaire like the PSS is.

Belief-based perceived stress. Belief-based perceived stress was assessed in the same manner as in Study 1 (using the PSS). The only notable difference is that individuals completed two versions of the PSS: the original, and a version that asked about stressful events in the past week only. This was to ensure the timespan covered by our performance- and belief-based measures of stress were approximately the same. Replication analyses for this study (i.e., Study 2 analyses aiming to replicate Study 1 results) use the original PSS, and confirmatory analyses for this study use the modified measure (modified (week) $\alpha = .85$, original (month) $\alpha = .88$).

Cognitive flexibility. We collected two measures of cognitive flexibility in this study. The first measure was identical to Study 1 (i.e., cognitive flexibility estimated using a standard Rescorla-Wagner model). The second measure was a canonical global/local task, constituting a more traditional measure of cognitive flexibility, similar to what has been previously collected in prior studies on cognitive control and reappraisal (McRae et al., 2012). During the task (Hedden & Gabrieli, 2010), participants were shown a series of large letters (S or H) comprising smaller letters (S or H) and were asked to attend to a particular level (global or local) and identify the letter via button press. The color of the letters was used to indicate which level to focus on (purple for local, white for global). Participants completed the task in blocks. Possible block types were limited to congruent (i.e., global and local matched) nonshifting (i.e., the same level was indicated for every trial) global-focused, congruent nonshifting local-focused, congruent shifting, incongruent nonshifting global-focused, incongruent nonshifting local-focused, and incongruent shifting. Each block consisted of 12 trials and was presented twice in random order (144 total trials). Reaction times were averaged for all shift versus nonshift trials. A switch cost metric was computed by subtracting average nonshift RTs from average shift RTs. This latter, traditional metric of cognitive flexibility was taken to further scrutinize whether the null results with cognitive flexibility in Study 1 were attributable to our novel operationalization of the construct.

Working memory. Working memory was assessed using the same procedures as in Study 1.

Analysis plan. The same general analysis plan used in Study 1 was employed here. First, we began by replicating all our results from Study 1. This involved quantifying the direct effects of capacity and tendency on perceived stress, determining whether they interacted, verifying if tendency alone was a better model for perceived stress than capacity alone, and testing for indirect effects of cognitive flexibility. Next, we examined how associations between capacity, tendency, and wellbeing changed when varying the assessment modality (incorporating belief- and performance-based metrics, respectively). We then searched for indirect effects (because of the large number of possible models, we only ran mediation/indirect effect analyses if we found a significant direct effect between reappraisal and perceived stress). These analyses were preregistered on the OSF (osf.io/sk3y2). Post hoc exploratory analyses focusing on unpacking differential associations between capacity and tendency on wellbeing are described at the end.

Results

Overview. Study 2 results are structured in the following way. First, we replicate findings from Study 1. This involves replicating all of Study 1's confirmatory (quantifying effects of capacity and tendency on perceived stress and testing for indirect effects of cognitive flexibility) and exploratory analyses (effect of tendency over and above capacity, better fitting tendency model over capacity model, interactive effects of capacity and tendency on stress, and interactive effects of cognitive flexibility and capacity/tendency on stress). Afterward, we conducted confirmatory analyses to test our Study 2 hypotheses, which involved examining how associations between capacity, tendency, and wellbeing changed when varying the assessment modality (incorporating belief- and performance-based metrics, respectively) and searching for indirect effects. These analyses were preregistered on the OSF (osf.io/sk3y2). Post hoc exploratory analyses focusing on unpacking differential associations between capacity and tendency on wellbeing are described at the end.

Diagnostics and basic descriptive statistics.

Regression diagnostics. We ran the same set of regression diagnostics here as we did in Study 1 (described in the online supplemental materials). To be consistent with Study 1, we report 99% bootstrapped confidence intervals (10,000 iterations).

Bivariate correlations and descriptive statistics. Descriptive statistics and bivariate correlations between all study variables are displayed in Table 2.

In Study 2, reappraisal capacity and tendency were indeed correlated, but only within measurement modality. In other words, performance-based capacity and tendency were positively correlated ($r = .20$, $p = .033$, 99% CI [−.01, .41]), belief-based capacity and tendency were positively correlated ($r = .67$, $p < .001$, 99% CI [.45, .82]), but belief-based capacity and performance-based tendency ($r = -.14$, $p = .133$, 99% CI [−.37, .11]), as well as performance-based capacity and belief-based tendency ($r = .06$, $p > .250$, 99% CI [−.19, .28]), were uncorrelated. Belief-based and performance-based capacity, in addition to belief-based and performance-based tendency were respectively uncorrelated with one another (capacity: $r = .08$, $p > .250$, 99% CI [−.18, .33]; tendency: $r = -.11$, $p > .250$, 99% CI [−.35, .16]).

The computationally derived index of cognitive flexibility (α) was inversely correlated with working memory ($r = -.24$, $p = .010$, 99% CI [−.46, .01]) and was unassociated with all other measures. The traditional, set-shifting index of cognitive flexibility was positively correlated with performance-based capacity ($r = .20$, $p = .031$, 99% CI [−.05, .42]) and negatively correlated with belief-based tendency ($r = -.20$, $p = .034$, 99% CI [−.43, .03]).

Performance-based perceived stress was inversely correlated with belief-based capacity ($r = -.19$, $p = .045$, 99% CI [−.44, .08]) and positively correlated with belief-based perceived stress ($r = .41$, $p < .001$, 99% CI [.20, .61]). Belief-based perceived stress was negatively correlated with belief-based capacity ($r = -.49$, $p < .001$, 99% CI [−.67, −.27]) and tendency ($r = -.48$, $p < .001$, 99% CI [−.70, −.20]).

Replicating Study 1 analyses.

Replicating Study 1's preregistered analyses.

Measuring the effects of capacity and tendency on stress. First, we conducted a simple linear regression wherein we regressed belief-based perceived stress scores on performance-based reappraisal capacity and replicated the null results obtained in Study 1 ($B = .002$, $SE = .003$, 99% CI [−.006, .010], $p > .250$, $R^2 = .002$). These results did not depend on whether belief-based perceived stress was reported from the prior week or prior month. We conducted another simple linear regression by regressing belief-based perceived stress on belief-based tendency and replicated the significant effects observed in Study 1 ($B = -.262$, $SE = .051$, 99% CI [−.379, −.118], $p < .001$, $R^2 = .233$). These results did not depend on whether belief-based perceived stress was reported from the prior week or prior month.

Estimating indirect effects of cognitive flexibility. We replicated our null results from Study 1, finding that there was no significant indirect effect of cognitive flexibility on performance-based capacity and belief-based stress (Indirect effect = .000, bootstrapped $SE = .0003$, 99% CI [−.0007, .0007]), even after accounting for working memory (Indirect effect = .000, bootstrapped $SE = .0003$, 99% CI [−.0007, .0006]). The same held true for the indirect effect of cognitive flexibility on belief-based tendency and belief-based stress (Indirect effect = .0086, bootstrapped $SE = .0092$, 99% CI [−.0041, .0315]), even when accounting for working memory (Indirect effect = .0092, bootstrapped $SE = .0107$, 99% CI [−.0048, .0364]).

Replicating Study 1's exploratory analyses.

Do reappraisal capacity and tendency predict stress over and above each other? We attempted to determine whether the effect of belief-based reappraisal tendency on belief-based perceived stress from the prior week remained significant after adjusting for performance-based capacity. Multiple regression analysis confirmed this was indeed the case (performance-based capacity: $B = .000$, $SE = .003$, 99% CI [−.007, .009], $p > .250$; belief-based tendency: $B = -.262$, $SE = .051$, 99% CI [−.380, −.115], $p < .001$, adjusted $R^2 = .220$). The association between belief-based tendency dropped out of significance if using perceived stress

Table 2
Bivariate Correlations Between Study 2 Variables

Variable	*M* (*SD*)	1	2	3	4	5	6	7	8	9
1. Capacity – Performance	29.89 (18.32)	1								
2. Capacity – Belief	4.82 (1.21)	.08	1							
3. Tendency – Performance	−.2365 (0.60)	$.20^{*}$	−.14	1						
4. Tendency – Belief	4.59 (1.10)	.06	$.67^{***}$	−.11	1					
5. Perceived stress – Performance	2.61 (0.50)	.02	$-.19^{*}$	.06	−.18	1				
6. Perceived stress – Belief	2.87 (0.59)	.01	$-.49^{***}$	.18	$-.48^{***}$	$.41^{***}$	1			
7. Cognitive flexibility – Alpha	.57 (0.31)	.01	−.10	−.04	−.15	.13	.07	1		
8. Cognitive flexibility – Set shift cost	.28 (0.11)	$.20^{*}$	−.16	.06	$-.20^{*}$	.06	.02	.14	1	
9. Working memory	3.64 (1.22)	.12	−.17	−.01	−.06	−.11	−.00	$-.24^{*}$	−.11	1

Note. Capacity refers to reappraisal capacity; Tendency refers to reappraisal tendency; Performance-based refers to estimates taken from a laboratory task (reappraisal) or daily survey (perceived stress). Cognitive flexibility – Alpha refers to the computationally estimated alpha parameter; Cognitive flexibility-Set shift cost refers to the difference in shift minus nonshift mean reaction times on the global local task; Working memory refers to d' scores calculated from our n-back task (2-back design).
* $p < .05$. *** $p < .001$.

scores assessed over the prior month, as opposed to the prior week ($B = -.072$, $SE = .041$, 99% CI [−.179, .043], $p = .082$, adjusted $R^2 = .008$).

Do capacity and tendency interact to predict wellbeing? In Study 1 we ran an exploratory analysis to test whether, as has been suggested in the literature (Ford et al., 2017), capacity and tendency may interact to predict wellbeing, but we did not find evidence to support this hypothesis. In Study 2, we sought to confirm this result and ran another moderation analysis in which performance-based capacity, belief-based tendency (both standardized), and their interaction were entered as predictors of stress. We observed a conditional effect of performance-based capacity ($B = .030$, $SE = .057$, 99% CI [−.108, .185], $p > .592$; conditional effect of belief-based tendency: $B = -.299$, $SE = .054$, 99% CI [−.425, −.142], $p < .001$; interaction term: $B = -.133$, $SE = .061$, 99% CI [−.297, .031], $p = .025$, adjusted [$R^2 = .252$]) such that a one unit increase in capacity, while holding tendency constant, is expected to change the association between tendency and perceived stress by −.133 (or vice versa). In other words, the effect of reappraisal capacity on perceived stress becomes stronger given greater levels of tendency and the effect of reappraisal tendency on perceived stress becomes stronger given greater levels of capacity.

Comparing model fits for reappraisal capacity and tendency predicting stress. We next sought to replicate Study 1's exploratory findings that tested whether the model predicting belief-based stress from belief-based tendency evinced a better fit than the model predicting belief-based stress from performance-based capacity. We used the same bootstrapping approach as described in the Study 1 results. The difference in R^2 values was .233 ([belief-based stress ∼ belief-based tendency] - [belief-based stress ∼ performance-based capacity]) with a 95% CI of [.066, .415]. Given the confidence interval around our bootstrapped sampling distribution did not include the null value of zero, we can conclude that the model with tendency as a predictor significantly fits better compared to capacity. This result held when examining perceived stress scores measuring stress from the prior month (difference in $R^2 = .222$; 95% [.057, .404]).

Testing whether cognitive flexibility moderates the association between reappraisal skills and stress. In Study 1, we considered that we may have theoretically mis-specified our model and reasoned that cognitive flexibility may moderate the association between facets of reappraisal and stress. Here we attempt to replicate the null results of that analysis. As before, we ran two moderation models, one in which flexibility moderated the link between capacity and stress, and another in which flexibility moderated the link between tendency and stress. In both models, we failed to reject the null hypothesis in these analyses, as we did in Study 1, concluding again that cognitive flexibility does not act as a moderator (first model, Capacity × Flexibility: $B = .007$, $SE = .061$, 99% CI [−.167, .155], $p > .250$, adjusted $R^2 = -.026$; second model, Tendency × Flexibility: $B = -.023$, $SE = .056$, 99% CI [−.139, .151], $p > .250$, adjusted $R^2 = .203$).

Study 2 analyses: Incorporating performance- and belief-based measurement modalities.

Confirmatory results.

Probing relationships between stress and capacity across different assessment modalities. We sought to determine whether the associations observed above would hold across different types of assessments (i.e., performance v tendency). First, we tested whether performance-based stress was predicted by performance-based capacity; it was not (Table 3, row 1). By contrast, we found that belief-based capacity was inversely related to belief-based stress (Table 3, row 2). Performance-based tendency was not related to performance-based stress (Table 3, row 3), whereas belief-based tendency was indeed inversely related to belief-based stress (as reported above).

Testing Indirect effects of cognitive flexibility on performance- and belief-based associations. Analyses of indirect effects showed that neither index of cognitive flexibility accounted for the significant links reappraisal and perceived stress described above (even when controlling for working memory).

Exploratory results.

Probing cross-modal relationships between stress and tendency. As reported above, we found a null association between belief-based perceived stress and performance-based reappraisal capacity. To probe whether this null association was attributable to these measures being obtained through different modalities (self-reported beliefs vs. performance), we next tested whether performance-based *tendency* also failed to predict belief-based perceived stress. This was indeed the case—performance-based tendency was not predictive of belief-based stress (Table 3, row 5).

Table 3
Regression Results for Select Study 2 Models

Analysis	Slopes	*SE*	99% CI	Fit (Adj-R^2)
1. PB stress ~ PB capacity	*B* = .001	.002	[−.004, .005]	.001
2. BB stress ~ BB capacity	*B* = −0.246	.042	[−.330, −.163]	.248
3. PB stress ~ PB tendency	*B* = .024	.089	[−.149, .206]	.001
4. BB stress ~ BB tendency	*B* = −0.262	.051	[−.379, −.118]	.233
5. BB stress ~ PB tendency	*B* = .091	.112	[−.124, .311]	.010
6. BB stress ~ BB capacity + BB tendency	*B cap* = −0.156	.066	[−.284, −.023]	.276
	B ten = −0.147	.079	[−.303, .013]	
7. PB stress ~ PB capacity + PB tendency	*B cap* = .001	.002	[−.006, .007]	−.016
	B ten = .020	.092	[−.213, .273]	

Note. *B* refers to unstandardized coefficients; Fit column reflects adjusted R^2 values when multiple predictors are present in the model; BB refers to belief-based, PB refers to performance-based, Capacity/cap refers to cognitive reappraisal capacity, Tendency/ten refers to cognitive reappraisal tendency, Stress refers to perceived stress, ~ used as 'predicted by' operator.

Do capacity and tendency differentially predict perceived stress? We next tested whether the independent effects of belief-based capacity and tendency on belief-based stress held when controlling for one another. We first addressed this above as a replication of a Study 1 analysis, and here we expand to incorporate different measurements of capacity and tendency (e.g., performance, belief-based). Multiple regression results showed that capacity still evinced significant, inverse associations with belief-based stress, over and above tendency, whereas the effect of tendency, over and above capacity, was no longer significant (Table 3, row 6). For thoroughness, we performed the same analysis with performance-based measures of stress, capacity, and tendency. Results from this analysis remained null (Table 3, row 7).

Teasing capacity and tendency apart from performance and beliefs. Our final set of exploratory analyses attempted to tease apart associations between stress and capacity/tendency (regardless of measurement modality) and stress and measurement modality (regardless of whether measuring capacity or tendency). For purposes of clarity and brevity, we have included the detailed methods and results of these analyses in the online supplemental materials. The main point to note here is that we found weak but consistent evidence that belief-based composites of reappraisal skills were better predictors of wellbeing than performance-based ones.

General Discussion

Cognitive reappraisal is a putatively adaptive form of emotion regulation that has been linked to several wellbeing outcomes. The present study sought to test whether reappraisal capacity and tendency are differentially associated with wellbeing, whether cognitive flexibility accounts for links between reappraisal and wellbeing, and whether associations between reappraisal and perceived stress generalize across belief- and performance-based measures of reappraisal capacity and tendency. Study 1 is one of few to test both reappraisal tendency and capacity independently in the same sample and Study 2 is the first—to our knowledge—to analyze both belief- and performance-based scores of reappraisal to attempt to identify the critical component of reappraisal that accounts for its efficacy in improving wellbeing outcomes. Across both studies, we found no evidence that cognitive flexibility accounts for the association between either facet of reappraisal (capacity or tendency) and perceived stress, regardless of measurement modality. Our results generally indicated that individuals who endorsed greater belief-based scores of reappraisal capacity and tendency tended to report significantly lower perceived stress, although we found no evidence for a similar relationship between perceived stress and performance-based measures of reappraisal. These findings have several theoretical and practical implications.

Theoretical Implications

Our first key finding was that we did not find evidence that cognitive flexibility mediates or moderates the association between either facet of reappraisal (capacity or tendency) and perceived stress. These null findings could be interpreted multiple ways. First, it could indicate that other untested executive functions (e.g., self-monitoring) are indeed important for linking reappraisal to psychological adjustment whereas cognitive flexibility is not. However, another possibility is that reappraisal is an emergent system—a system that is greater than the sum of its parts and no single mechanistic feature is more privileged than others. Although we found an association between working memory and reappraisal capacity, it is still possible that individual executive functions may not be lynchpins for reappraisal's success in engendering adjustment outcomes given that working memory did not account for the association between reappraisal and perceived stress.

Although prior work has linked executive functions such as cognitive flexibility (McRae et al., 2012) and working memory (Scult et al., 2017) to both capacity and tendency, we found that cognitive flexibility was not significantly related with either facet of reappraisal, whereas working memory was related with capacity. It is plausible that cognitive reappraisal is indeed linked to cognitive flexibility, but only as it is assessed by certain paradigms. For instance, one prior study that found a link between cognitive flexibility and reappraisal capacity used a set-shifting task to measure cognitive flexibility (McRae et al., 2012), whereas we initially used a probabilistic reversal learning task. If the relationship between reappraisal and cognitive flexibility varies as a function of the context in which flexibility is measured (e.g., perceptual, value-based, etc.), then it would suggest that different types of cognitive flexibility have different associations with reappraisal (Malooly et al., 2013). Consistent with this possibility is our finding that performance-based reappraisal capacity was positively associated with a traditional measure of cognitive flexibility but not the measure assessed in the context of reversal learning. Another possible methodological reason for differences across studies, however, is that significance may be driven by variability in sample size and composition—we sampled more than 100 individuals from an ethnically diverse population of college undergraduates, whereas other studies report smaller, community samples (e.g., McRae et al., 2012) or larger, less ethnically diverse samples (e.g., Scult et al., 2017) with different age and sex compositions.

Our second key finding was that we observed that individuals who reported possessing strong reappraisal skills (i.e., higher capacity, greater tendency) also reported relatively low levels of perceived stress. Intriguingly, when examined simultaneously, belief-based capacity was significantly predictive of perceived stress while belief-based tendency was weakly related to perceived stress. One interpretation of these results suggests that simply perceiving oneself to have better reappraisal skills may engender reduced perceived stress. One reason for this may lie in perceptions of control (see Study 1 Interim Discussion). Prior work suggests that individuals who believe that emotions are controllable utilize emotion regulation strategies more effectively (Ford & Gross, 2018). This is particularly relevant in the context of stress, given that beliefs about stressor controllability predict the effectiveness of other forms of emotion regulation such as fear extinction (Hartley, Gorun, Reddan, Ramirez, & Phelps, 2014). Although we did not explicitly assess participants' beliefs about the nature of emotional processes, it is plausible that individuals who perceive better control of their emotions likely are more likely to believe that emotions are inherently controllable. Of course, it could alternatively be that individuals who are less stress-prone believe that they are better at regulating their emotions. That performance-based measures largely turned up nonsignificant associations with stress is also notable, because it suggests a disconnect between individuals' metaperceptions of affective experience and their objective reappraisal performance. Alternatively, it possible that the manner in which computerized measures assess reappraisal is simply not related to how reappraisal is implemented outside the laboratory. Future studies should work to unpack this effect in addition to searching for potential hidden moderators.

Practical Considerations

The findings reported here could have practical implications for programs aimed at improving wellbeing, such as psychotherapy approaches. For instance, cognitive–behavioral therapy (CBT), one of the most widely employed and successful forms of psychotherapy (Covin, Ouimet, Seeds, & Dozois, 2008; Durlak, Fuhrman, & Lampman, 1991; Stewart & Chambless, 2009), is predicated upon helping clients learn to reappraise emotionally distressing events and situations. Although more work is needed to unpack this effect, therapies like CBT could benefit from the knowledge that individuals who possess greater self-efficacy in reappraisal skills tend to show better adjustment (at least in terms of perceived stress).

Moreover, our findings make an important contribution to the recent discussion about how bolstering executive function may enhance emotion regulation (Cohen & Mor, 2018; Scult et al., 2017). Generally, because executive function may have a causal role in emotion regulation success (Cohen & Mor, 2018), there has been optimism that training it may help bolster emotion regulation and, consequently, wellbeing outcomes. However, our results highlight need for caution in thinking about this issue moving forward, posing important caveats. Executive function is a multifaceted concept. As we have noted here, emotion regulation strategies are supported by *several* executive function processes. Because a large number of executive processes were not exhaustively assessed in the current study, we cannot conclusively say whether links between reappraisal and wellbeing are supported by one (or a few) privileged executive functions. That said, we *can* conclude there is no evidence to suggest neither cognitive flexibility nor working memory ability fully explains the relationship between reappraisal and perceived stress. This is relevant for the matter of selecting an appropriate facet of executive function to train to improve emotion regulation. In addition, because beliefs about reappraisal were related to adjustment in our sample, it may be inefficient to focus on methods that help improve one's objective performance on reappraisal skills and instead focus on ways to bolster self-efficacy in extant reappraisal skills.

Another practical consideration is whether to continue to use laboratory reappraisal tasks if they continue to fail to show associations with meaningful markers of wellbeing. It is likely that these laboratory tasks do measure reappraisal—they have face validity—but perhaps in a different way than how reappraisal is executed in more naturalistic settings. These tasks typically prompt participants with a cue, require they reappraise the meaning of a static emotional image, and then immediately rate their affect. By contrast, in everyday life individuals must respond to dynamic situations that they have differing degrees of agency over, regulate emotions via their own internal imperatives, and may not always have the opportunity to pause to meta-analyze their own beliefs. Creating paradigms that are low-dimensional distillations of their real-world targets is tractable for controlled laboratory research but often requires sacrificing elements of ecological validity (Jolly & Chang, 2019). Future work ought to continue to rigorously weigh these competing methodological considerations when assessing the role of emotion regulation in wellbeing. This might include designing assessment techniques that make use of naturalistic stimuli or ecological measurements that capture reappraisal as it unfolds (e.g., analyzing a participant's recollection of a stressful memory, asking a participant to recall their thought process shortly after being present with an emotionally evocative stimulus, etc.).

Limitations

There are several limitations to the current study that merit consideration for future work. First, one salient limitation is in the generalizability of the results. Although our sample was relatively large ($N \approx 250$) and racially and ethnically diverse, our results nevertheless come from a sample of college undergraduates and may not generalize to other populations. Similarly, we focused exclusively on perceived stress as an outcome, yet it is entirely possible that the associations described in this report differ across different types of wellbeing (Ford et al., 2017). Perceived stress may have different relationships with performance-based markers of capacity and tendency than measures of mood, anxiety, or social function. We also assumed that our global and momentary self-report assessments served as adequate markers of belief- and performance-based constructs. Although this practice is consistent with the general literature and helps simplify aspects of our experimental design, we do note that these techniques may not be perfect belief- and performance-based assessments. This is of particular concern as it regards performance-based assessments since such a term implies objectivity when it may not necessarily be warranted. With that mind, we note that we simply have no way of further verifying this notion, so we discuss it here so that readers are aware of this limitation. One final consideration rests on recent reports questioning the reliability of computerized, task-based measures of self-regulation (Enkavi et al., 2019). We found that several measures had adequate, but not stellar, reliability (e.g., performance-based tendency) and one (computationally derived cognitive flexibility) had quite poor reliability. Relatedly, the fact that cross-method assessments of the same construct did not correlate may be indicative of acceptable, but less-than-optimal, psychometric properties (though the psychometrics of our measures were not bad, overall). Another interpretation of divergence in cross-method assessments of the same construct is that they signal an interesting substantive result—that one's beliefs about their reappraisal abilities and use are not good predictors of their actual abilities. Future methodological work should be conducted to even better flesh out the psychometric validity of the measures used here to help settle this question. This could involve revising existing computerized paradigms to be compatible with sophisticated psychometric evaluation tools such as item response theory, developing additional computerized tasks and determining whether they all map on to a latent common factor, and analyzing specific stimuli in standardized stimulus sets (e.g., IAPS, OASIS) to determine which are better suited for computerized tasks and which are not.

Conclusion

In conclusion, our study represents a first attempt to assess associations between reappraisal capacity, tendency, and a measure of wellbeing (perceived stress), while simultaneously investigating whether cognitive flexibility helps support such associations. Our results highlight the importance of measuring both reappraisal capacity and tendency, and the importance of the manner in which capacity and tendency are measured, as they may have different relationships with wellbeing. These findings give credence to the possibility that the complex and dynamic cognitive processes that support cognitive reappraisal are emergent, such that one single component of reappraisal is unlikely to solely account for its utility.

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