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Common Executive Function Predicts Reappraisal Ability but Not Frequency

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Cognitive reappraisal is an emotion-regulation strategy that positively impacts various facets of adaptive functioning (e.g., interpersonal relations, subjective well-being). Although reappraisal implicates cognitive processing, no clear consensus has been reached regarding its cognitive correlates. Therefore, we examined how executive function (EF)—i. e., a group of general-purpose control abilities comprising working memory, inhibition, and shifting—would be associated with task-based reappraisal ability and self-reported reappraisal frequency. Using a latent-variable approach, we found that the shared variance among EF facets (i.e., common EF)—a general goal-management ability that facilitates the activation and maintenance of task-relevant goals—was positively related to reappraisal ability but not reappraisal frequency. However, the three EF components were not uniquely associated with either reappraisal ability or frequency. Further, when EF was conceptualized at the individual-task level, we found inconsistent patterns of associations between EF constituents and reappraisal. This underscores the need to measure all aspects of EF using multiple indicators at the latent-variable level. Our findings provide vital theoretical, methodological, and empirical insights into the cognitive correlates of reappraisal.

Keywords: reappraisal, emotion regulation, executive function, working memory, inhibition

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Cognitive reappraisal (*reappraisal* hereafter) is an emotion-regulation strategy that involves the effortful or automatic reinterpretation of an emotion-eliciting event to upregulate or downregulate its emotional impact (Gross, 2008; Gyurak et al., 2011; Pavlov et al., 2014; Wang et al., 2017; Zilverstand et al., 2017). Individuals who use reappraisal more frequently experience closer interpersonal relations and lower depressive symptoms, as well as higher levels of psychological and subjective well-being (Garnefski et al., 2001; Gross & John, 2003; John & Gross, 2004; McRae, Jacobs, et al., 2012). Given that reappraisal has been hypothesized to be supported by brain regions (e.g., the prefrontal cortex) that are responsible for domain-general cognitive control (e.g., Buhle et al., 2014; Ochsner & Gross, 2008), numerous studies have examined how individual differences in executive function (EF)—a collection of general-purpose regulatory processes—are related to reappraisal (Schmeichel & Tang, 2015).

Although empirical evidence corroborates the role of EF during reappraisal processes, a clear consensus has not emerged concerning the links between the multifaceted construct of EF—which involves inhibition, working memory updating, and shifting (Miyake et al., 2000)—and reappraisal. Furthermore, given that reappraisal ability (i.e., the capacity to successfully reappraise negative experiences) and reappraisal frequency (i.e., the habitual tendency to use reappraisal to regulate emotions) reflect separable constructs and have been shown to be dissimilarly correlated with EF processes (McRae, Jacobs, et al., 2012), we inquired whether the various EF facets would be asymmetrically associated with reappraisal ability and frequency. In light of these questions, we sought to investigate how the shared and unique variance among EF components are related to reappraisal ability and frequency using a latent-variable approach.

The Theoretical Construct of EF

EF represents a collection of higher-order control abilities that are essential for autonomous and purposive behaviors, such as abstract reasoning, problem-solving, and planning and organizing goal-directed activities (Banich, 2004; Elliott, 2003; Salthouse, 2005). While multiple theoretical definitions have been proposed for the construct of EF (Jurado & Rosselli, 2007), a well-established theoretical conceptualization of EF is the unity/diversity framework, as advanced by Miyake et al. (2000), which details three correlated, but separable, regulatory processes. Working memory updating (*working memory* hereafter) refers to the ability

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to retain and manipulate goal-relevant information within a mental workspace, as well as controlled retrieval from long-term memory (Friedman & Miyake, 2017). Inhibition is defined as the ability to suppress prepotent responses and task-irrelevant information to sustain task-relevant goals (Friedman & Miyake, 2004). Shifting involves the ability to switch back and forth between multiple tasks and mental sets (Monsell, 2003).

A recent formulation of the revised unity/diversity model specifies a common EF component, which reflects the shared variance among all EF abilities (i.e., unity), and the working-memory-specific and shifting-specific factors (i.e., diversity), which account for the remaining variance among working memory and shifting tasks after common variance has been extracted (Friedman & Miyake, 2017). In this revised model, no unique variance is left for inhibition as it is completely explained by the common EF factor. Specifically, the common EF factor has been suggested to represent the general EF ability to identify, activate, maintain, and monitor relevant goals—particularly in the face of interference from task-irrelevant goals, information, or distractors—and to use these goals to guide ongoing processing (Friedman & Miyake, 2017). The absence of an inhibition-specific factor can be accounted for by the fact that the ability to execute and maintain goals, as captured by the common EF factor, is an essential requirement for successful performance on all types of EF measures, and particularly for inhibition tasks (Friedman & Miyake, 2017).

The revised model has been substantiated by a growing body of evidence. For instance, neuropsychological studies found that performance on inhibition tasks was primarily driven by the general goal-management abilities that are representative of common EF (Banich & Depue, 2015; Chatham et al., 2012; Hampshire et al., 2010; Munakata et al., 2011), thereby, underscoring the centrality of common EF in explaining inhibition operations. Further, common EF has been shown to be a general requirement for all types of EF (Friedman & Miyake, 2017) and a prominent correlate of other cognitive abilities, such as fluid intelligence (Friedman et al., 2008) and language skills (Gooch et al., 2016); as well as various everyday behavioral outcomes, such as behavioral disinhibition (Herd et al., 2014), self-control (Friedman et al., 2011), substance abuse (Gustavson et al., 2017), procrastination (Gustavson et al., 2015), implicit racial bias (Ito et al., 2015), and trait worry (Gustavson et al., 2020).

Relations Between EF and Reappraisal

Previous studies suggest that reappraisal relies, in part, on EF. For instance, while neuroimaging studies do not directly measure the neural overlap between EF and reappraisal, they provide indirect evidence that similar brain regions are involved in both reappraisal and EF (Ochsner & Gross, 2005). Specifically, the ability to reappraise (e.g., thinking objectively to decrease emotional reactivity) negatively valenced stimuli (e.g., evocative pictures) is concomitant with (a) increased activation of the dorsolateral and ventrolateral prefrontal regions, which are known to be implicated in EF processes (Buhle et al., 2014); and (b) reduced activation of emotion-related regions, such as the amygdala and insula (Banks et al., 2007; Goldin et al., 2008; Kim & Hamann, 2007; Lévesque et al., 2003; Ochsner et al., 2002; Ochsner et al., 2004). Accordingly, these neuroimaging findings have motivated theoretical postulations on the roles of EF facets in reappraisal (McRae, Jacobs, et al., 2012; Schmeichel & Tang, 2015; Tang & Schmeichel, 2014). Specifically, inhibition likely assists in resolving competition among various situational interpretations by prioritizing desired reappraisals and suppressing undesired narratives. Working memory is possibly involved in gating and manipulating reappraisal-related information within a mental workspace while sustaining goal-relevant reappraisals, as well as the strategic and controlled retrieval of appropriate narratives from long-term memory. Shifting may be required in switching from goal-incongruent appraisals to more favorable reappraisals through reconfiguring existing situational interpretations and preventing the initial appraisal from proactively interfering with the shift to goal-congruent narratives. Given these theoretical considerations, a growing body of behavioral research has investigated the relation between each EF component (i.e., working memory, inhibition, and shifting) and reappraisal.

Working Memory

Previous empirical studies have demonstrated the relation between working memory and reappraisal. For instance, in a study by Schmeichel et al. (2008), participants completed a working memory measure (i.e., the operation-span task) and were instructed to either view a negatively valenced (i.e., disgust inducing) film clip naturally (*express* condition) or to adopt a detached, unemotional attitude and think about the film objectively (*reappraisal* condition). Schmeichel et al. demonstrated that individuals with better working memory reported lower levels of disgust in the reappraisal condition than in the express condition. However, those with poorer working memory did not show any differences between the two conditions, demonstrating the role of working memory in the regulation of negatively valenced stimuli through reappraisal.

Hendricks and Buchanan (2016) found that a more proficient ability to reappraise evocative pictures was associated with better working memory (assessed by the keep-track task). McRae, Jacobs, et al. (2012) observed a similar pattern when they examined the relation between various cognitive abilities—that is, inhibition, shifting, verbal ability, abstract reasoning, and working memory (as assessed by the operation-span task)—and reappraisal ability. Results indicated that more proficient working memory was positively correlated with the ability to reappraise negatively valenced pictures. Likewise, Pe, Raes, and Kuppens (2013) found that higher self-reported reappraisal frequency was related to lower negative affect in individuals with higher, but not those with lower, levels of working memory (assessed by the emotional *n*-back task). However, Liang et al. (2017) found that working memory (assessed by the number-memory task) was not linked to reappraisal ability. Taken together, while these findings demonstrate that working memory is generally linked to the reappraisal of negative experiences, the mixed evidence demonstrates the need for further research.

Inhibition

Empirical evidence has also lent support to the association between inhibition and reappraisal. For example, Tabibnia et al. (2011) compared differences in inhibition (assessed by the stop-signal task) and reappraisal ability (i.e., reinterpreting evocative pictures in nonnegative ways) between healthy individuals and methamphetamine-dependent individuals, who have been known to exhibit lapses in inhibition. Inhibition was positively correlated with reappraisal ability, and healthy individuals outperformed their methamphetamine-dependent counterparts on the inhibition and reappraisal tasks. Similarly, Salas et al. (2014) reported that individuals with focal damage to left fronto-parietal regions, relative to healthy controls, showed markedly greater difficulties in inhibition and spontaneous reappraisal generation (i.e., producing as many positive aspects of negatively valenced situations as possible), indicating that deficits in inhibition impair the ability to successfully reappraise negative situations.

Using experience sampling methods, Pe, Raes, Koval, et al. (2013) found that poorer inhibition (assessed by an affective proactive interference task) was associated with smaller increases and decreases in positive and negative affect, respectively, during self-reported reappraisal, which suggests that impaired inhibition for negative information curtails the benefits of reappraisal in daily life. In contrast, McRae, Jacobs, et al. (2012) failed to find relations between inhibition (assessed by the Stroop task) and reappraisal ability (i.e., reinterpreting negatively valenced stimuli objectively). Similarly, null findings were observed in other studies that examined the link between inhibition—as assessed by the stop-signal task (Hendricks & Buchanan, 2016) and the magnitude-size Stroop task (Liang et al., 2017)—and reappraisal ability. The literature suggests that inhibition is likely implicated in reappraisal—but the inconsistent evidence warrants further investigation.

Shifting

In contrast to the findings on working memory and inhibition, empirical evidence on shifting is noticeably scarce. For example, Malooly et al. (2013) examined whether reappraisal ability (i.e., adopting an objective mindset while viewing aversive film clips) would be related to performance on an affective shifting measure, in which participants had to sort a given picture according to affective (i.e., negative or positive) and nonaffective (i.e., one or no human beings or two or more human beings) task sets. Results indicated that higher reappraisal ability was associated with faster switching (i.e., lower switch costs) from affective to nonaffective task sets for negative images as well as faster switching from nonaffective to affective task sets for positive images. These findings imply that the ability to shift away from the negative aspects—as well as toward the positive aspects—of emotional material is concomitant with the reappraisal of negative emotions. Liang et al. (2017) showed that difficulties in shifting (assessed by the plus-minus task) corresponded with poorer detached (i.e., adopting an unemotional perspective), but not positive (i.e., reinterpreting negative aspects of situations in positive ways), reappraisal ability among older adults. Conversely, other studies found that reappraisal ability was either unrelated to shifting (as assessed by the number-letter task; Hendricks & Buchanan, 2016) or concomitant with more accurate, but slower, shifting performance (assessed by the global/local task; McRae, Jacobs, et al., 2012), signifying a speed-accuracy tradeoff. Collectively, the cumulative evidence highlights that reappraisal potentially implicates working memory and inhibition, albeit with equivocal findings for both. However, given the limited and mixed outcomes, the role of shifting in reappraisal is speculative at best.

Limitations of Past Research

Despite the accumulated evidence on the relation between EF and reappraisal, there are several notable limitations. First, previous studies have independently examined the relation of reappraisal with each aspect of EF (e.g., Schmeichel et al., 2008; Tabibnia et al., 2011). Given that EF components are intercorrelated (Miyake et al., 2000), the unique contributions of each EF process (after removing its shared variances with other EF processes) to reappraisal remains unknown. For instance, efficient performance on working-memory measures, such as the operation-span task, requires (a) inhibiting task-irrelevant processes (i.e., solving arithmetic problems) that interfere with task-relevant information (i.e., to-be-remembered items) and (b) shifting between the distractor and memory tasks (Draheim et al., 2016). Likewise, for task-switching paradigms, inhibition is required in the suppression of the prior task set, while working memory is involved in the deletion and insertion of irrelevant and relevant task sets, respectively, within a mental workspace (Monsell, 2003; Rubinstein et al., 2001). Hence, concurrent examination of the three facets of EF in a single study is essential to shed light on each constituent's unique contribution.

While theories that detail the unique roles of each EF in reappraisal have been proposed (Schmeichel & Tang, 2014), it is unclear whether the previously established positive findings for the relation of each EF factor to reappraisal reflect the unique variance of specific EF components or common variance (i.e., common EF) that is shared across all EF processes. To this end, we sought to disentangle the extent to which the shared and unique aspects of EF are related to reappraisal. Specifically, we posit that common EF may be implicated in the identification, selection, and implementation of situationally appropriate reappraisal strategies (e.g., reducing personal relevance to the emotion-eliciting event by adopting a detached and objective perspective, reinterpreting negative aspects of the situation positively, etc.) that are best suited to the needs of reappraisal goals (e.g., upregulation or downregulation of emotions). Additionally, common EF may support goal-relevant (e.g., positive or neutral) narratives by resisting interference from conflicting, goal-incongruent (e.g., negative) appraisals or nonrelevant environmental distractors. Our postulations are in line with past hypotheses maintaining that the ventrolateral prefrontal cortex—a region responsible for common EF operations such as selecting goal-relevant information and overriding prepotent responses (Badre & Wagner, 2007; Lieberman et al., 2007)—likely facilitates the selection of goal-congruent reappraisals and the suppression of goal-incongruent appraisals (Buhle et al., 2014; Silvers et al., 2014).

Second, a considerable number of behavioral studies, as well as neuroimaging studies that directly examined the neural correlates of EF and reappraisal, have relied on EF tasks that engage emotional stimuli (e.g., affective variants of the *n*-back task, proactive interference task, and task-switching paradigm; Malooly et al., 2013; McRae, Jacobs, et al., 2012; Pe, Raes, Koval, et al., 2013; Schweizer et al., 2013). Although the experimental instructions in affective EF tasks do not explicitly involve emotion regulation per se, the management and control of affective material has been shown to recruit implicit emotion-regulation processes (Braunstein et al., 2017). For instance, the affective *n*-back task, which requires participants to discern whether the valence of the word in the current trial matches the valence of the word two trials back, involves the updating of information within working memory as well as the regulation of emotional interference from affective stimuli on controlled performance. Indeed, affective EF tasks are often used as measures of implicit emotion regulation (Braunstein et al., 2017;

Buhle et al., 2010; Kappes & Bermeitinger, 2016). Moreover, studies have demonstrated that implicit emotion regulation engages similar prefrontal regions (e.g., right ventrolateral) that are activated during reappraisal (Burklund et al., 2014; Lieberman et al., 2007). Accordingly, the previously established findings between affective EF and reappraisal (Malooly et al., 2013; McRae, Jacobs, et al., 2012) are likely overestimated, and it is unclear whether these associations are driven by EF or emotion-regulation processes per se. Hence, dissociating EF processes from emotion-regulation mechanisms is crucial to more precisely understand how the two constructs are related.

A third limitation of past research is the reliance on single-task EF measures (e.g., McRae, Jacobs, et al., 2012; Pe, Raes, Koval, et al., 2013; Pe, Raes, & Kuppens, 2013; Schmeichel et al., 2008; Tabibnia et al., 2011), which can be problematic due to the task-impurity problem. Specifically, EF tasks tend to tap EF processes along with other task-specific non-EF abilities, as signified by the low, and often statistically nonsignificant, correlations between EF tasks observed in past studies (Foster et al., 2015; Miyake et al., 2000). To illustrate, although the operation-span task primarily taps working-memory performance, arithmetic proficiency is required during the distractor task and letter identification is required during the encoding of target letters. Similarly, the Stroop task principally assesses inhibition, as evidenced by the ability to suppress the automatic tendency to read the word, as well as the ability to identify and discriminate colors. On the one hand, it is plausible that task-specific idiosyncrasies in EF tasks may be responsible for the positive findings on the associations between EF and reappraisal, as reported in past studies (e.g., Schmeichel et al., 2008; Tabibnia et al., 2011). On the other hand, task-specific variance may obscure genuine relations between EF and reappraisal. Indeed, despite the general consistency in the literature, a few studies did not find direct relations between reappraisal ability and EF (McRae, Jacobs, et al., 2012; Pe, Raes, Koval, et al., 2013). Therefore, more rigorous methodological and statistical approaches are needed to circumvent the task-impurity issue in EF tasks.

The Present Study

In view of the aforementioned issues, the goals of this study are as follows. First, given that previous studies have explored the relations between reappraisal and each EF component independently (Schmeichel & Tang, 2014), we draw on the three-factor (i.e., inhibition, working memory, and shifting) and nested-factor (i.e., common EF, working-memory-specific, and shifting-specific factors) models to investigate the associations of EF constituents with reappraisal. Because the three-factor model partials out the common variance among EF tasks, it allows for investigation of the unique relation of each EF component to reappraisal. On the other hand, the nested-factor model affords simultaneous assessment of the associations of both the shared (i.e., common EF) and unique (i.e., working-memory-specific and shifting-specific factors) aspects of EF processes with reappraisal.

Second, given that previous studies relied on affective EF tasks, it is unclear whether EF or emotion-regulation processes in affective EF tasks account for the previously established relations between affective EF and reappraisal (Malooly et al., 2013; McRae, Jacobs, et al., 2012). Thus, we used EF tasks with neutral or nonaffective stimuli to circumvent the confounding effect of emotional stimuli on EF and better distinguish EF abilities from reappraisal processes.

Third, to address the task-impurity problem associated with EF tasks, we used a latent-variable approach based on multiple tasks for each EF dimension. The latent-variable approach provides a purer estimation of each EF component by accounting for task-specific idiosyncrasies and measurement errors in EF tasks (Miyake et al., 2000). Therefore, we sought to examine how our findings would differ when EF was modeled at the latent-variable level, relative to the individual-task level.

Fourth, we assessed how EF would be related to self-reported and task-based measures of reappraisal, which are two indices of reappraisal commonly used in past research (e.g., McRae, Jacobs, et al., 2012; Pe, Raes, Koval, et al., 2013). Notably, the two measures of reappraisal are not analogous (McRae, 2013). Specifically, self-reported measures of reappraisal capture the frequency with which individuals habitually use reappraisal as an emotion-regulation strategy. In contrast, task-based measures of reappraisal assess individuals' ability to successfully achieve their goals of regulating emotional experiences. Indeed, previous work has alluded to the asymmetric associations of EF with reappraisal ability and frequency (McRae, Jacobs, et al., 2012). Notably, given that similar neural substrates have been suggested to be implicated in performance on reappraisal and EF tasks (e.g., Goldin et al., 2008; Ochsner et al., 2004), we hypothesized that EF would be associated with reappraisal ability. In contrast, we conjectured that EF would not necessarily be related to reappraisal frequency, which may be influenced by motivational and dispositional factors (e.g., optimism, well-being; Gross & John, 2003). Additionally, to ascertain that the relation between EF and reappraisal was not confounded by third-variable effects, we controlled for crucial covariates—such as intelligence, gender, depression, age, and social desirability—that have been shown to affect either EF or reappraisal (Arffa, 2007; Ehring et al., 2010; McRae, Gross, et al., 2012, McRae, Jacobs, et al., 2012; McDermott & Ebmeier, 2009; Nolen-Hoeksema & Aldao, 2011; Urbanek et al., 2009).

Fifth, we examined whether reappraisal frequency could moderate the associations between EF and reappraisal ability. Cohen et al. (2012) found that while negatively valenced stimuli interfered with inhibitory control (assessed by the flanker task), this emotional interference effect was reduced in individuals who used reappraisal more frequently than in those who used reappraisal less frequently. This finding suggests that more frequent use of reappraisal may be concomitant with an improved inhibition ability to attenuate undesired negative affect driven by negative material. Therefore, we examined whether the relations of EF to reappraisal ability would be stronger for individuals who used reappraisal with higher, relative to those with lower, frequency.

Method

Participants

One hundred and seventy students from a local university were recruited for the study in exchange for course credit or a monetary reward ($30). This sample size is comparable to past studies that have used multiple measures to assess EF components (e.g.,

Table 1

Descriptive Statistics of Predictors, Covariates, and Criterion Variables

Variable	*M*	*SD*	Min	Max	Skewness	Kurtosis	Reliability[a]
Predictors							
Executive function (EF)[b]							
Working memory							
Operation span	0.85	0.15	0.02	1.00	−2.25	7.16	.76
Rotation span	0.68	0.19	0.07	1.00	−0.83	0.65	.73
Symmetry span	0.78	0.17	0.00	1.00	−1.57	3.61	.66
Inhibition							
Antisaccade	0.73	0.17	0.26	1.00	−0.76	−0.27	.93
Go/no-go	0.48	0.19	0.01	0.91	−0.18	−0.54	.93
Stroop[c]	14.18	1.92	1.29	16.19	−2.57	11.37	.79
Shifting							
Color shape[c]	14.20	1.90	3.24	17.19	−2.70	12.50	.80
Animacy locomotion[c]	13.94	2.01	4.17	17.32	−1.90	5.77	.89
Magnitude parity[c]	13.43	2.09	3.39	17.24	−1.36	3.52	.86
Demographics and covariates							
Gender (% female)[d]	66.3	—	—	—	—	—	—
Depressive symptoms	2.07	0.54	1.00	3.80	0.62	0.12	.67
Social desirability	4.17	0.81	1.88	5.75	−0.31	−0.19	.65
Fluid intelligence	6.41	1.93	0.00	9.00	−0.77	0.25	.67
Age (years)	21.61	1.98	18.00	28.00	—	—	—
Education[e]	14.00	1.76	9.00	23.00	—	—	—
Criterion							
Reappraisal frequency	4.62	0.99	2.33	7.00	−0.20	−0.38	.86
Reappraisal ability							
Reappraisal trials[f]	3.19	0.66	1.33	4.73	−0.46	0.18	.89
Parcel 1	3.27	0.69	1.40	4.80	−0.39	0.01	—
Parcel 2	2.95	0.77	1.00	4.80	−0.34	−0.22	—
Parcel 3	3.36	0.76	1.20	5.00	−0.41	−0.22	—
Baseline trials[f]	2.66	0.66	1.33	4.60	0.38	−0.23	.88
Parcel 1	2.61	0.74	1.00	5.00	0.43	0.18	—
Parcel 2	2.72	0.74	1.00	4.40	0.14	−0.41	—
Parcel 3	2.64	0.76	1.20	4.60	0.37	−0.34	—

[a] For the following EF tasks, reliability estimates were calculated using Spearman-Brown adjusted split-half correlations: Stroop, color-shape, animacy-locomotion, and magnitude-parity tasks. For all other measures, reliability estimates were computed based on Cronbach's α. [b] Due to administrative and technical errors, data for the following EF tasks were missing: antisaccade (*n* = 1), go/no-go (*n* = 1), operation span (*n* = 1), symmetry span (*n* = 1), Stroop (*n* = 4), animacy-locomotion (*n* = 1), and magnitude-parity (*n* = 2). [c] For the Stroop, color-shape, animacy-locomotion, and magnitude-parity tasks, average bin scores were reverse-coded such that higher values denote better performance. [d] Gender was coded as 0 = *female*, 1 = *male*. [e] Education level was indexed by total number of years of formal education. [f] Responses for the reappraisal task were reverse coded such that higher values indicate higher levels of reappraisal ability.

Miyake et al., 2000; Unsworth et al., 2014). Moreover, for a structural equation model with a maximum of 6 latent variables and 26 manifest variables (see Results), a minimum sample size of 161 is required to detect a medium effect size of .30 (Soper, 2018). Further, Monte Carlo simulation with 1,000 iterations showed that our sample had sufficient statistical power (>80%) to detect an EF-reappraisal effect of .27 to .29 (see Results). Given that the data for this study are a subset of a larger project, only variables relevant to the study's hypotheses are reported (see Table 1 for descriptive statistics).

Materials

Reappraisal Frequency

The six-item reappraisal subscale of the Emotion Regulation Questionnaire (Gross & John, 2003) was adapted to index the frequency with which cognitive reappraisal was used on an everyday basis (e.g., "When I want to feel more positive emotion, I change what I'm thinking about"; 1 = *almost never*, 7 = *almost always*). Higher scores reflected greater reappraisal frequency.

Reappraisal Ability

To assess the ability to reframe affective experiences, a reappraisal task by McRae, Jacobs, et al. (2012) was implemented.[1] Participants viewed a series of pictures and had to either (a) perceive the picture naturally (e.g., "allow yourself to continue to feel whatever it was you were feeling previously about the picture, as you naturally would") or (b) reappraise the picture to reduce negative emotions (e.g., "by imagining ways the situation could improve for the better, or identifying aspects of the situation that are not as bad as they seem").

In each trial, either of two instruction words was first be presented (2 s). Specifically, the instruction "Look" indicated that participants should view the pictures naturally, while "Decrease" denoted that participants should reappraise the pictures. Next, the target picture, surrounded by colored frames—which served to remind participants what they were supposed to do—was shown (8 s). Green and blue frames were paired with "Look" and "Decrease" instructions, respectively. Subsequently, participants

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[1] We thank Dr. Kateri McRae for sharing the reappraisal task with us.

responded to the question "How negative do you feel?" on a 5-point scale (1 = *not at all*, 5 = *very negative*). Thereafter, an intertrial interval with the instruction "Relax" was shown (1 s to 3 s). There were 15 trials of each type: look instruction with neutral picture, look instruction with negative picture, decrease instruction with negative picture. Negative affect ratings were reverse coded such that higher values reflected greater degrees of reappraisal. Higher values for the "Decrease Negative" condition, relative to the "Look Negative" condition, indicated better reappraisal ability.

As a preliminary check on whether participants reappraised the negatively valenced stimuli in the reappraisal trials, we compared scores for the "Decrease Negative" and "Look Negative" trials. Ratings for the pictures were significantly less negative on the reappraisal trials than on the baseline trials, $t(169) = 11.98$, $p < .001$. At the end of the reappraisal task, we administrated an open-ended funnel questionnaire that asked about the types of strategies participants used during the task. We found that the predominant strategies used were related to reappraisal (e.g., thinking that the situation would improve for the better), rather than nonreappraisal strategies (e.g., not looking at the screen).

Working Memory

We adopted three complex-span measures to assess working memory (Foster et al., 2015), which comprised distractor and memory components. The dependent variable in each working-memory measure was the proportion of correctly remembered items over the total number of to-be-remembered items; higher values indicated better performance.

Operation Span. In the distractor task, participants verified whether a given arithmetic problem (e.g., $[2 \times 2] - 1 = 3$) was true or false by clicking on the boxes shown on the screen. To prevent participants from rehearsing the to-be-remembered items during the distractor task (Foster et al., 2015); participants' responses were timed such that if their response time (RT) exceeded 2.5 *SD* above their mean RT, as calculated during practice trials, then that trial was counted as an error. Thereafter, a to-be-encoded letter was presented on the screen for 800 ms. The set size (i.e., the total number of math problem and letter sequences) of a trial varied from three to seven and was randomly presented. Upon the presentation of a 4 × 3 matrix of letters, participants were directed to recall and click the appropriate letters in the correct order. The matrix remained on screen until a response was submitted.

Before the main test, a series of practice trials were presented. First, participants were shown four trials that required the recollection of a sequentially presented string of letters (i.e., two trials of set sizes two and three each). Subsequently, they completed 15 trials of arithmetic problems; each participant's mean RT in completing the distractor trials was recorded. Last, they completed three trials of set size two that contained both math problems and letter sequences. In the main task, participants were presented with two blocks comprising trials with varying set sizes from three to seven (one trial per set size) that were presented in a random order.

Rotation Span. Similarly, participants were presented with a distractor task, in which they indicated whether a rotated letter was correctly oriented or a mirrored image of the letter. Next, participants had to remember the length (either short or long) and direction (pointing in one of eight different directions) of an arrow. Participants had to recall all previously presented arrow stimuli in the correct order upon the presentation of all 16 possible combinations of directionality and length of the arrows. The total number of letter-arrow sequences (i.e., set size) varied from two to five per trial. All other aspects were identical to the operation-span task.

Symmetry Span. As a distractor task, participants evaluated whether a geometric figure was symmetrical along its vertical axis. Next, they were asked to remember the locations of red squares on a 4 × 4 grid. During recall, upon presentation of the same 4 × 4 grid (without the red squares), participants reported the positions of the previously presented red squares in the correct order. The set size varied from two to five per trial and was randomized across two blocks of trials. All other methodological aspects were identical to the other complex span tasks.

Inhibition

Three measures were used to tap the ability to deliberately inhibit prepotent, dominant, or automatic responses (Friedman & Miyake, 2004).

Antisaccade. As adapted from Unsworth and McMillan (2014), participants were asked to identify, as quickly and accurately as possible, a target stimulus (i.e., *B*, *P*, or *R*) that was flashed briefly on one side of the screen while ignoring a distracting cue on the other side of the screen. In each trial, a fixation point first appeared in the center of the screen for a variable amount of time (one of six possible times, from 200 ms to 2,200 ms with 400 ms intervals). A visual cue ("=") was flashed either to the left or right relative to the fixation point (11.33° of visual angle) for 100 ms. Next, a blank screen (50 ms) was shown, followed by the second appearance of the flashing cue (100 ms) to further increase attentional capture and distractibility of the cue. Subsequently, a 50-ms blank screen appeared, followed by the target stimulus, which was positioned 11.33° to the left or right of the fixation point, for 150 ms. Thereafter, the target stimulus was first masked by the letter *H* (50 ms) and then by the number *8* until a response was given.

Critically, the flashing cue and the target appeared of opposite sides of the screen (i.e., when the flashing cue appeared on the left side of the screen, the target appeared on the right side and vice versa). Participants completed 24 practice trials, followed by 72 main test trials. Since the antisaccade trials signified the ability to resist attentional capture by the distracting cue, the dependent variable was the proportion of correct responses on the antisaccade trials, with higher scores representing better performance.

Go/No-Go. Adapted from McVay and Kane (2009), participants had to respond as quickly and accurately as possible, by pressing the spacebar on the keyboard, when the non-*X* letters were shown (i.e., go trials) and refrain from responding when the target *X* letter was shown (i.e., no-go trials). In every trial, a letter stimulus was first presented for 400 ms, followed by a blank screen that lasted for 900 ms or until a response key was pressed. There were 445 go trials and 55 no-go trials. As the target stimulus was infrequently presented (11% of the time), the proportion of correct responses on the no-go trials was used as the dependent variable.

Stroop. Adapted from Unsworth and McMillan (2014), participants had to identify the color of a word instead of reading the word (e.g., "blue" printed in red ink). In each trial, participants saw a fixation point (750 ms) followed by the target word and had to indicate, as quickly and accurately as possible, the color of the target word by pressing the *R* (red), *Y* (yellow), *G* (green), or *B* (blue) key. The target word remained on the screen for 2,000 ms or until a response key was entered. Two types of trials were randomly presented: (a) 144 congruent trials with the target word printed in the same color as the word (e.g., "green" printed in green ink) and (b) 72 incongruent trials with the target word printed in a different color (e.g., "red" printed in blue ink). The preponderance of the congruent, relative to the incongruent, trials served to increase task difficulty for the critical incongruent trials. Before the main trials, 10 practice trials were presented. The dependent measure was reverse-coded bin scores, which integrated both accuracy and RT scores (see Binning Procedure), higher values indicated better performance.

Shifting

Three measures based on the task-switching paradigm were used to assess efficiency in shifting back and forth between multiple mental sets (Monsell, 2003). The dependent variable for all three measures was reverse-coded bin scores, with higher scores denoting better shifting abilities (see Binning Procedure).

Color Shape. Participants sorted bivalent figures (i.e., green circle or red triangle) based on the color rule (i.e., green or red) or the shape rule (i.e., circle or triangle) by pressing the *D* (i.e., circle or red) or *K* (i.e., green or triangle) keys. The task cue for the color rule was a color gradient and the cue for the shape rule was a row of black squares. In every trial, a fixation point (350 ms) was first shown, followed by the cue and, after a delay (250 ms), the target. The cue and target remained on the screen until a response was given. The intertrial interval, signified by a blank screen, was 700 ms. There were four blocks (36 trials each) that comprised an equal number of switch trials (e.g., shape rule followed by color rule) and repeat trials (e.g., color rule for two consecutive trials), and the first trial in each block was excluded. The trial order was randomized, and the maximum number of consecutive repeat trials was set at four. There were 70 switch trials and 70 repeat trials.

Magnitude Parity. Similarly, participants sorted bivalent numbers (i.e., 2 or 7) based on either the magnitude rule (i.e., smaller or greater than five) or the parity rule (i.e., odd or even) by pressing the *D* (i.e., odd number or less than five) or *K* (i.e., even number or more than five) keys. A row of circles that varied in size represented the cue for the magnitude rule and rows of odd-numbered and even-numbered squares denoted the cue for the parity rule. All other methodological aspects were identical to the color-shape task.

Animacy Locomotion. Participants sorted a target (i.e., plane or rabbit) according to the animacy rule (i.e., animate or inanimate) or the locomotion rule (i.e., flying or nonflying) by pressing the *D* (i.e., animate or flying) or *K* (i.e., inanimate or nonflying) keys. The cues for the animacy and locomotion rules were pictures of dog paws and roads, respectively. All other methodological aspects were identical to other shifting tasks.

Covariates

Fluid intelligence was assessed using a nine-item short form of Raven's Standard Progressive Matrices (RSPM-SF; Bilker et al., 2012). Participants saw a series of geometric designs, each with a missing segment, and had to select, from six to eight options, the segment that completed each visual pattern. A higher number of correct responses denoted better fluid intelligence.

Depressive symptoms (in the past week; e.g., "I felt that everything I did was an effort") was indexed by a 10-item short form of the Center for Epidemiological Studies-Depression survey (CES-D-10; Andresen et al., 1994) based on a 4-point scale (1 = *rarely or none of the time*, 4 = *most of the time*). Social desirability was evaluated by the eight-item impression management subscale (e.g., "I sometimes tell lies if I have to"; 1 = *not true at all*, 7 = *very true*) of the Balanced Inventory of Desirable Responding-Short Form (BIDR-SF; Hart et al., 2015). Demographic information was obtained using a background questionnaire.

Binning Procedure

Given that bin scores have been shown to offer better reliability, validity, and sensitivity in the detection of larger effect sizes than pure RT or accuracy scores (Draheim et al., 2016; Hughes et al., 2014), we used bin scores to index inhibition costs in the Stroop task and switching efficiency in the three shifting measures. Following Draheim et al. (2016), bin scores were computed as follows. First, the following were excluded: (a) incorrect trials, (b) trials with RTs below 200 ms, and (c) trials with RTs that deviated from each participant's mean by more than 3 *SD*. Second, each participant's mean RT for all repeat trials was subtracted from the RT of every accurate switch trial; for the Stroop task, the mean RT for all congruent trials was deducted from the RT of each accurate incongruent trial. Third, all participants' difference scores were rank ordered into deciles as a group and assigned bin values ranging from 1 to 10, with 1 containing the fastest 10% and 10 the slowest 10%. Inaccurate switch (for shifting tasks) or incongruent (for Stroop task) trials were assigned a bin value of 20. Fourth, a single bin score for each participant was computed by averaging the bin values for accurate and inaccurate switch (for shifting tasks) or incongruent (for Stroop task) trials. Last, bin scores were reverse coded, with higher values reflecting better performance.

Procedure

The study comprised three sessions, with a 1-day interval between each session. In the first session, participants completed the reappraisal task and a battery of surveys that included the demographic background questionnaire and RSPM-SF (i.e., fluid intelligence). In the second session, the EF tasks were administered in the following order: operation-span, antisaccade, color-shape, and rotation-span tasks. Subsequently, participants completed a series of surveys that included the reappraisal subscale of the Emotion Regulation Questionnaire. In the third session, the order of the EF tasks was as follows: magnitude-parity, go/no-go, symmetry-span, animacy-locomotion, and Stroop tasks. Last, participants finished several questionnaires that included the CES-D-10 (i.e., depressive symptoms) and BIDR-SF (i.e., social desirability). The order of the EF tasks was fixed for every participant, with the restriction that no two consecutive tasks assessed the same EF component (see Miyake et al., 2000). This was done to minimize potential noise introduced by different task orders, thereby rendering order effects consistent across participants and allowing for performance between individuals to be directly comparable. The entire study lasted approximately 3 hr. The study procedure was approved by the university's Institutional Review Board (IRB-19–061-A061 [719]).

Analysis Plan

Latent-variable analyses were conducted on M*plus* 7.4 (Muthén & Muthén, 2015) using full information maximum likelihood estimation. EF components were modeled as exogenous latent variables. Indicators for the working-memory latent factor were operation-span, rotation-span, and symmetry-span tasks. Indicators for the inhibition latent factor were antisaccade, go/no-go, and Stroop tasks. Indicators for the shifting latent factor were color-shape, magnitude-parity, and animacy-locomotion tasks. Indicators for the common-EF latent factor comprised all nine EF tasks.

Reappraisal ability and frequency were modeled as endogenous latent variables. For the latent variable of reappraisal ability, indicators were generated by parceling, which is suitable for unidimensional scales and has been shown to have psychometric and model-fit advantages (e.g., enhancement of scale communality, increase in the common-to-unique ratio for each indicator, and reduction of random error; Little et al., 2002). Specifically, the latent variable of reappraisal ability was formed based on three parceled indicators driven by responses on all "Decrease Negative" trials. To control for baseline ratings without reappraisal for negatively valenced images, the latent variable of baseline emotional reactivity was generated by three parceled indicators from responses on the "Look Negative" trials. For the latent variable of reappraisal frequency, the indicators were responses to the six items on the reappraisal subscale within the Emotion Regulation Questionnaire.

To ascertain that the indicators reflected their intended constructs, the adequacy of the measurement models was first examined through confirmatory factor analyses. Thereafter, a series of structural equation modeling was performed to examine the links between EF and reappraisal processes. In particular, we examined the unique relations between the three-factor EF model with reappraisal ability and frequency by analyzing how the two reappraisal processes are related to each EF component separately and simultaneously. Further, to assess the extent to which the shared variance among EF components would be concomitant with reappraisal, we tested the associations between reappraisal ability and frequency with the common EF factor in the nested-factor EF model. Following this, the covariates of intelligence, gender, depressive symptoms, age, and social desirability were added to the structural models to control for third-variable effects.

To examine whether reappraisal frequency moderates the relations of reappraisal ability with EF, latent moderated structural equation modeling was conducted by regressing reappraisal ability on the three EF constituents, as well as their interaction terms with reappraisal frequency, based on the three-factor and nested-factor models. To determine whether our results would differ when the EF constituents were alternatively modeled at the individual-task level (as opposed to the latent-variable level), regression analyses were performed by regressing reappraisal ability and frequency on all nine EF tasks individually.

In evaluating model fit, the following criteria were adopted: root-mean-square error of approximation (RMSEA) values equal to or below .08 and .06 to denote acceptable and good fit, respectively; standardized root-mean-squared residual (SRMR) values equal to or below .08; comparative fit index (CFI) close to or greater than .95; and normed chi-square values (χ^2/df) lesser than two as indications of good fit (Hu & Bentler, 1998; Tabachnick & Fidell, 2001). All reported estimates were standardized. Zero-order correlations between all variables of interest are shown in Table A1 in Appendix A. Data and details on study materials are available through the Open Science Framework (https://osf.io/tmxnh/; Toh & Yang, 2020).

Results

Measurement Models

Confirmatory factor analyses were conducted to first ascertain an adequate model fit for the EF measurement model. The three-factor and nested-factor EF models had acceptable to good fit to the data, and all factor loadings of indicators were significant ($ps < .01$; see Figures 1 and 2). Consistent with Miyake et al. (2000), all EF components for the three-factor model were significantly correlated with each other ($ps < .001$). To ascertain that the three-factor and nested-factor models were the best-fitting models, we also compared their model fit with that of alternative models. Specifically, the one- and two-factor models had poorer model fit than both the nested-factor model and the three-factor model (see Table 2). Consequently, we proceeded with further analyses using the three-factor and the nested-factor EF models.

The full measurement model was evaluated by adding reappraisal ability (while controlling for baseline emotional reactivity) and reappraisal frequency to the three-factor and nested-factor EF models (see Table 2 for model-fit indices). For the three-factor EF model with reappraisal processes, the full measurement model fitted the data well, $\chi^2(174) = 226.74$, $\chi^2/df = 1.30$, RMSEA = .042, SRMR = .052, CFI = .965. Similarly, for the nested-factor EF structure with reappraisal processes, the model fit was good, $\chi^2(171) = 219.73$, $\chi^2/df = 1.28$, RMSEA = .041, SRMR = .050, CFI = .968. In both models, all factor loadings of indicators were significant ($ps < .001$). Further, correlating the residuals of the first two items of the reappraisal scale, which defined the concepts of positive and negative emotions (John, 2009), significantly improved the fit of both models based on the three-factor ($\Delta\chi^2(1) = 31.77$, $p < .001$) and the nested-factor ($\Delta\chi^2(1) = 31.81$, $p < .001$) EF frameworks. Accordingly, these models were used for the subsequent structural equation modeling.

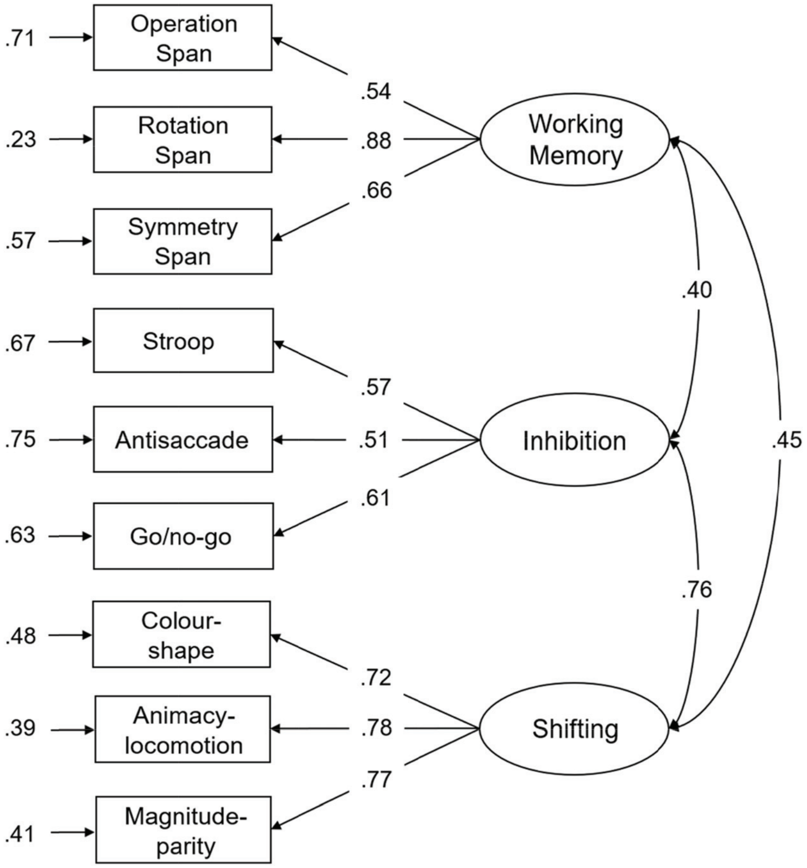
Structural Models

To examine the associations of EF with reappraisal ability and frequency, we performed structural equation modeling based on the three-factor and nested-factor EF models. All structural models fitted the data well (see Table 2). For the structural model based on the three-factor EF model (Model 4 in Table 3), none of the EF processes were significantly associated with reappraisal ability ($\gamma s < .36$, $ps > .05$) or frequency ($\gamma s < .16$, $ps > .43$), and results remained the same when covariates were added to the model ($\gamma s < .29$, $ps > .11$). These findings indicate that when intercorrelations between EF latent factors were controlled for, the three EF constituents did not account for unique variance in reappraisal ability or frequency.

Subsequently, we assessed the relations of reappraisal ability and frequency with each of the three EF latent variables separately (see Models 1 to 3 in Table 3). Results showed that more proficient inhibition was concomitant with higher reappraisal ability ($\gamma = .27$, $SE = .08$, $p = .001$) but not reappraisal frequency ($\gamma = .09$, $SE = .11$, $p = .388$). The relation between inhibition and reappraisal ability remained significant even when covariates were

Figure 1

Three-Factor Executive Function (EF) Model With Standardized Estimates



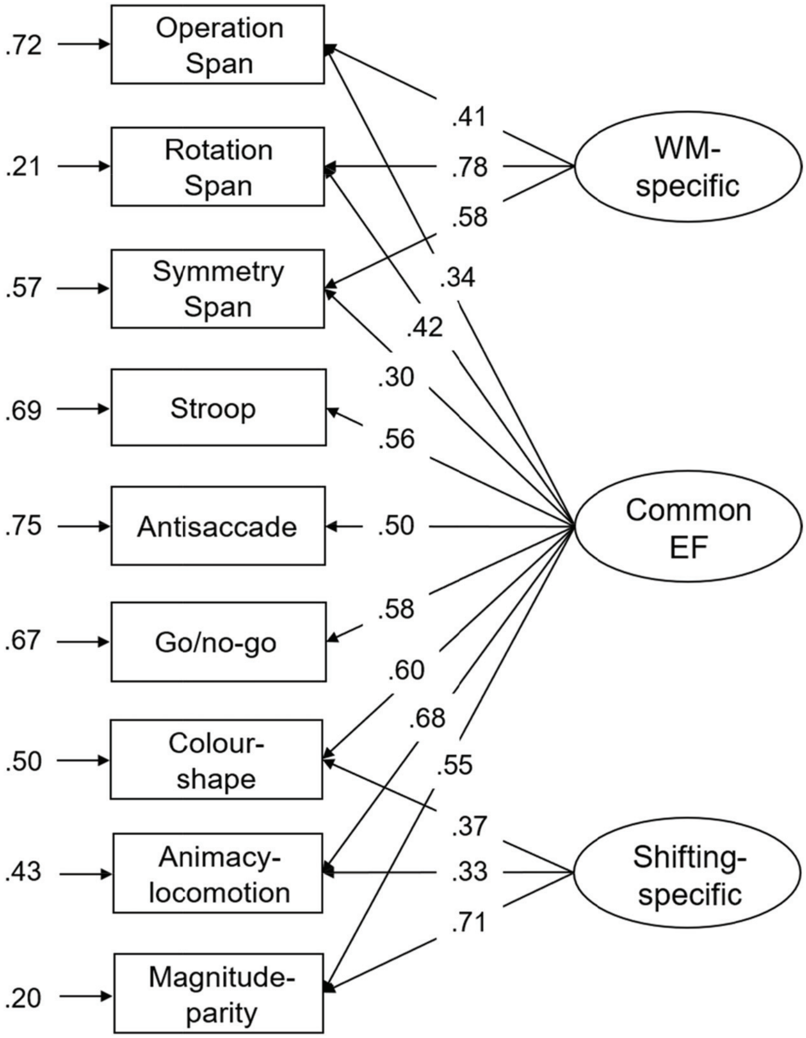
Note. Ovals represent latent variables and rectangles denote manifest variables (indicators). Values for the longer, single-headed arrows signify factor loadings, while values for the shorter, single-headed arrows represent error variances. Values for the curved, double-headed arrows indicate interfactor correlations. All factor loadings, residual variances, and interfactor correlations were statistically significant at .05 level.

controlled for (γ = .27, *SE* = .10, *p* = .007). Shifting was significantly associated with reappraisal ability (γ = .15, *SE* = .07, *p* = .043), but not frequency (γ = .13, *SE* = .09, *p* = .136); however, this relation was no longer significant when covariates were controlled for (γ = .15, *SE* = .08, *p* = .050). Working memory was not related to reappraisal ability or frequency, with or without the inclusion of covariates (γs < .06, *p*s > .40). The results, when the three EF components were analyzed separately, show that only inhibition is reliably associated with reappraisal ability, while the other EF components are related to neither reappraisal ability nor reappraisal frequency.

We now turn to the structural model based on the nested-factor EF framework (Model 5 in Table 3). Crucially, common EF, but not working-memory-specific or shifting-specific factors, was positively associated with reappraisal ability (γ = .29, *SE* = .08, *p* < .001); none of the EF constituents were related to reappraisal frequency (γs < .12, *p*s > .24). When covariates were added to the model, the path coefficient of common EF on reappraisal ability remained significant (γ = .29, *SE* = .09, *p* = .002; see Figure 3). Further, we obtained similar patterns of results when reappraisal ability (i.e., mean score for “Decrease Negative” trials adjusted for mean score for “Look Negative” trials) and frequency (i.e., mean score for reappraisal frequency subscale) were modeled as manifest, instead of latent, variables. Specifically, common EF was positively coupled with reappraisal ability (γ = .28, *SE* = .08, *p* < .001), which remained significant even when covariates were controlled for (γ = .27, *SE* = .09, *p* = .002). Altogether, results from the nested-factor EF structure, in contrast to the null results from the three-factor EF model, demonstrate that common EF is associated with reappraisal ability—but not reappraisal frequency—even when covariates are controlled for.

Next, we conducted latent moderated structural equation analyses to examine the interactions between reappraisal frequency and the various EF facets in the three-factor and nested-factor models. To this end, these interaction terms were separately added to the existing three-factor and nested-factor models. None of the interaction terms were significant in the three-factor model when the three EF components were assessed simultaneously (γs < .24, *p*s > .08) or separately (γs < .12, *p*s > .34). Likewise, null results were obtained for the interaction terms in the nested-factor model

Figure 2
Nested-Factor Executive Function (EF) Model With Standardized Estimates



Note. Ovals represent latent variables and rectangles denote manifest variables (indicators). Values for the longer, single-headed arrows signify factor loadings, while values for the shorter, single-headed arrows represent error variances. All factor loadings and residual variances were statistically significant at .05 level. WM = working memory.

(γs $< .23$, *p*s $> .16$). These findings indicate that reappraisal frequency does not moderate the effects of EF constituents on reappraisal ability. Further, reappraisal frequency was not associated with EF (see Figure 3). While the link between reappraisal frequency and ability was in the expected positive direction, it did not reach statistical significance ($\gamma = .12$, $SE = .07$, $p = .071$). These findings signify that higher frequency of reappraisal does not correspond to better reappraisal ability or EF.

Regression Analyses

To examine how individual EF tasks would be related to reappraisal ability and frequency, regression analyses were performed by regressing reappraisal ability and frequency on each of the nine EF tasks (see Table 4). While several relations between EF tasks and reappraisal ability reached statistical significance, there were no consistent patterns of association. For instance, although the operation-span task was associated with reappraisal ability, the other two working-memory tasks were not. Of the inhibition tasks, only the antisaccade and go/no-go tasks were affiliated with reappraisal ability. For the shifting tasks, the animacy-locomotion task was related to reappraisal ability, while the color-shape task was associated with reappraisal frequency. Accordingly, in contrast to findings from the latent-variable analyses, results at the individual-task level highlight inconsistent associations between EF and reappraisal ability and frequency.

Table 2
Fit Indices for Measurement and Structural Models

Model	χ^2	*df*	χ^2/df	RMSEA	SRMR	CFI
EF measurement models						
One-factor model	124.50	27	4.61	.146	.090	.754
Two-factor models						
Inhibition-WM merged	93.80	26	3.61	.124	.092	.829
Inhibition-shifting merged	48.28	26	1.86	.071	.050	.944
WM-shifting merged	114.98	26	4.42	.142	.087	.775
Three-factor model	37.88	24	1.58	.068	.042	.965
Nested-factor model	33.24	21	1.58	.059	.039	.969
Full measurement models (with reappraisal)						
Three-factor EF model	194.97	173	1.13	.027	.049	.985
Nested-factor EF model	187.92	170	1.11	.025	.047	.988
Structural models						
Independent-EF models						
WM						
Unadjusted model	101.88	85	1.20	.034	.053	.986
Adjusted model[a]	177.40	149	1.19	.033	.067	.978
Inhibition						
Unadjusted model	93.57	85	1.10	.024	.052	.993
Adjusted model[a]	182.54	149	1.22	.036	.069	.972
Shifting						
Unadjusted model	88.83	85	1.05	.016	.051	.997
Adjusted model[a]	160.33	149	1.08	.021	.064	.991
Three-factor EF models						
Unadjusted model	198.47	177	1.12	.027	.056	.986
Adjusted model[a]	301.90	269	1.12	.027	.065	.979
Nested-factor EF models						
Unadjusted model	191.49	174	1.10	.024	.054	.988
Adjusted model[a]	294.98	266	1.11	.025	.064	.982

Note. EF = executive function; WM = working memory; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual; CFI = comparative fit index.
[a] Adjusted models include intelligence, gender, depressive symptoms, age, and social desirability as covariates.

Additional Analyses

We performed additional analyses to supplement our core findings. First, we examined whether our results would differ when alternative performance indices, such as RT difference scores and linear integrated speed-accuracy score (LISAS; Liesefeld & Janczyk, 2019; Vandierendonck, 2017), were used for the Stroop task and the three shifting measures (i.e., color-shape, animacy-locomotion, and magnitude-parity tasks). Given that LISAS scores are generated separately for the critical and baseline conditions, difference scores are ultimately required to obtain a single index for the Stroop effect and switch costs for the structural equation models. Prior to the structural equation modeling, we examined the measurement models based on each performance index for the three-factor and nested-factor models using confirmatory factor analysis. Model fit indices and factor loadings for all measurement models are summarized in Tables B1–B3 in Appendix B. Of the three performance scores, bin scores demonstrated the best model fit and the most consistent pattern of factor loadings for all EF factors in both the three-factor and nested-factor models. In contrast, RT and LISAS difference scores exhibited highly varied factor loadings for inhibition in the three-factor model and inconsistently significant factor loadings for the common EF factor in the nested-factor model, thereby demonstrating the inability to model the common-EF factor. Accordingly, the findings from our confirmatory factor analyses suggest that bin scores, compared with RT and LISAS difference scores, are most appropriate for purposes of the latent-variable approach. Next, we examined the structural models for the three performance scores using structural equation modeling. All standardized path coefficients are summarized in Table B4 in Appendix B. When the three EF factors were assessed independently, the positive relation between inhibition and reappraisal ability was consistently significant for all three performance indices across the unadjusted and adjusted models ($\gamma s > .24$, $ps < .027$). In the three-factor model in which the three EF factors were simultaneously assessed, no consistent associations were found between EF dimensions and reappraisal ability and frequency for the three performance scores for the unadjusted and adjusted models. We did not proceed to test the nested-factor model for RT and LISAS difference scores because of factor incoherence of the common-EF factor in the measurement models (see Table B3 in Appendix B). Importantly, our main findings obtained for the independent-EF models (Models 1 to 3) and the three-factor model (Model 4) using bin scores correspond to those based on RT and LISAS difference scores.

Second, given that several indicators of the EF factors—such as the Stroop and color-shape tasks—exhibited high kurtosis (see Table 1), we reanalyzed our data using full information maximum likelihood estimation with robust standard errors (MLR), which is the recommended approach to address multivariate nonnormality (Kline, 2015). Notably, the MLR results largely parallel our main findings. Specifically, when the three EF facets were individually assessed, inhibition was associated with reappraisal ability in both the unadjusted ($\gamma = .27$, $SE = .10$, $p = .005$) and adjusted ($\gamma = .27$, $SE = .11$, $p = .014$) models. For the three-factor model, no

Table 3

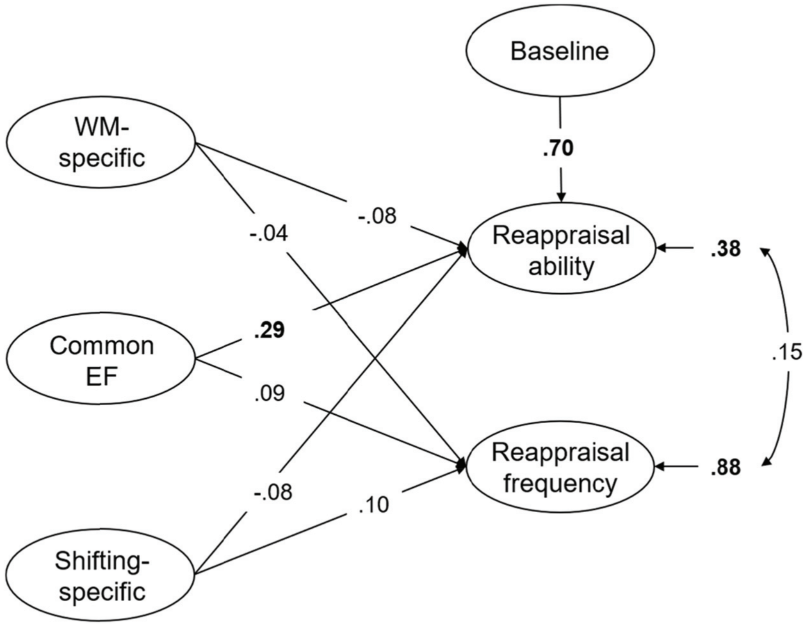
Standardized Parameter Estimates for the Independent-EF Constituents and the Three-Factor and Nested-Factor Models

Model	Unadjusted model		Adjusted model with covariates	
	Reappraisal ability	Reappraisal frequency	Reappraisal ability	Reappraisal frequency
Model 1				
Focal predictor				
Working memory	.06 (.07)	.02 (.09)	.04 (.08)	.01 (.10)
Control variable				
Baseline	**.70 (.05)**	—	**.70 (.05)**	—
Covariates				
Intelligence	—	—	.03 (.07)	.02 (.09)
Gender	—	—	**.21 (.08)**	.03 (.09)
Depressive symptoms	—	—	**−.16 (.06)**	−.14 (.08)
Age	—	—	−.13 (.08)	.10 (.09)
Social desirability	—	—	.03 (.06)	**−.27 (.07)**
Model 2				
Focal predictor				
Inhibition	**.27 (.08)**	.09 (.11)	**.27 (.10)**	.06 (.12)
Control variable				
Baseline	**.69 (.05)**	—	**.70 (.05)**	—
Covariates				
Intelligence	—	—	−.07 (.08)	−.01 (.09)
Gender	—	—	**.20 (.08)**	.02 (.09)
Depressive symptoms	—	—	**−.15 (.06)**	−.14 (.08)
Age	—	—	−.13 (.08)	.10 (.09)
Social desirability	—	—	.03 (.06)	**−.27 (.07)**
Model 3				
Focal predictor				
Shifting	**.15 (.07)**	.13 (.09)	.15 (.09)	.15 (.09)
Control variable				
Baseline	**.70 (.05)**	—	**.70 (.05)**	—
Covariates				
Intelligence	—	—	−.01 (.07)	−.04 (.08)
Gender	—	—	.22 (.08)	.04 (.09)
Depressive symptoms	—	—	**−.16 (.06)**	−.14 (.08)
Age	—	—	−.13 (.08)	.09 (.09)
Social desirability	—	—	.03 (.06)	**−.27 (.07)**
Model 4 (three-factor EF model)				
Focal predictors				
Working memory	−.04 (.09)	−.05 (.11)	−.04 (.09)	−.05 (.11)
Inhibition	.36 (.18)	−.01 (.21)	.29 (.18)	−.06 (.21)
Shifting	−.10 (.17)	.16 (.20)	−.03 (.16)	.20 (.19)
Control variable				
Baseline	**.69 (.05)**	—	**.70 (.05)**	—
Covariates				
Intelligence	—	—	−.04 (.08)	−.01 (.09)
Gender	—	—	**.21 (.08)**	.04 (.09)
Depressive symptoms	—	—	**−.15 (.06)**	−.14 (.08)
Age	—	—	−.13 (.08)	.09 (.09)
Social desirability	—	—	.03 (.06)	**−.27 (.07)**
Model 5 (nested-factor EF model)				
Focal predictors				
Working-memory-specific	−.08 (.08)	−.04 (.10)	−.08 (.08)	−.04 (.10)
Common EF	**.29 (.08)**	.10 (.10)	**.29 (.09)**	.09 (.12)
Shifting-specific	−.12 (.10)	.07 (.12)	−.08 (.10)	.10 (.12)
Control variable				
Baseline	**.69 (.05)**	—	**.70 (.05)**	—
Covariates				
Intelligence	—	—	−.06 (.08)	−.02 (.09)
Gender	—	—	**.20 (.08)**	.04 (.09)
Depressive symptoms	—	—	**−.14 (.06)**	−.14 (.08)
Age	—	—	−.13 (.08)	.09 (.09)
Social desirability	—	—	.03 (.06)	**−.27 (.07)**

Note. EF = executive function. Values denote standardized estimates with standard errors in parentheses. Gender was coded as 0 = *female*, 1 = *male*. Significant values are marked in boldface, $p < .05$.

Figure 3

Nested-Factor Executive Function (EF) Model Predicting Reappraisal Ability and Reappraisal Frequency



Note. Covariates (i.e., intelligence, gender, depressive symptoms, age, and social desirability), factor indicators (i.e., nine tasks for EF factors, six items for reappraisal frequency, and three parcels each for reappraisal ability and frequency), and residual correlations between indicators are not depicted for brevity. All coefficients shown are standardized; parameter estimates in boldface attained statistical significance at .05 level. Values on the longer, single-headed arrows signify path coefficients. Values for the smaller, single-headed arrows represent residual variances. Values on the curved, double-headed arrows indicate correlation coefficients. WM = working memory.

significant associations between EF and reappraisal ability and frequency were observed when all EF constituents were examined simultaneously in the unadjusted and adjusted models. For the nested-factor model, common EF was related to reappraisal ability, but not reappraisal frequency, in both the unadjusted ($\gamma = .29$, $SE = .09$, $p = .001$) and adjusted ($\gamma = .29$, $SE = .11$, $p = .008$) models. Therefore, our core findings hold true even when corrected for nonnormality.

Third, we examined whether reappraisal ability would be associated with more accurate but slower shifting performance in our data set, as seen in McRae, Jacobs, et al. (2012). Specifically, we individually assessed how the relations between the latent factors

Table 4

Standardized Regression Coefficients for Individual EF Tasks

	Unadjusted model		Adjusted modelwith covariates	
Measure	Reappraisal ability	Reappraisal frequency	Reappraisal ability	Reappraisal frequency
Working memory				
Operation span	**.16 (.06)**	−.01 (.08)	**.16 (.07)**	−.02 (.08)
Rotation span	.05 (.06)	.05 (.08)	.02 (.07)	.05 (.08)
Symmetry span	−.02 (.06)	−.07 (.08)	−.03 (.07)	−.07 (.08)
Inhibition				
Antisaccade	**.18 (.06)**	−.01 (.08)	**.15 (.07)**	.01 (.08)
Go/no-go	**.17 (.06)**	.01 (.08)	**.16 (.06)**	.02 (.08)
Stroop	.07 (.06)	.11 (.08)	.08 (.07)	.11 (.08)
Shifting				
Color shape	**.12 (.06)**	**.16 (.08)**	.11 (.06)	**.18 (.08)**
Animacy locomotion	**.15 (.06)**	.06 (.08)	**.15 (.07)**	.06 (.08)
Magnitude parity	.06 (.06)	.06 (.08)	.07 (.07)	.10 (.08)

Note. EF = executive function. Values denote standardized regression coefficients with standard errors in parentheses. Significant values are marked in boldface, $p < .05$.

of reappraisal ability and shifting would differ when the latter was indexed by RT and accuracy difference scores. Notably, reappraisal ability was not associated with shifting when RT ($\gamma = .01$, $SE = .10$, $p = .978$) or accuracy ($\gamma = .09$, $SE = .08$, $p = .302$) difference scores were used. Hence, we did not find evidence that reappraisal is associated with slower, but more cautious, shifting performance (cf. McRae, Jacobs, et al., 2012).

Fourth, past work has suggested that individuals with better EF may engage in spontaneous emotion regulation to manage negative affect arising from mood-induction procedures (e.g., recalling autobiographical memories), even in the absence of explicit instructions to do so (e.g., Schmeichel & Demaree, 2010; Tang & Schmeichel, 2014). Therefore, it is plausible that EF may influence affect ratings on baseline emotional reactivity (i.e., "Look Negative" trials). To examine this possibility, we included additional pathways from the three EF facets to baseline emotional reactivity when each EF factor was assessed independently, as well as the three-factor and nested-factor models. Notably, none of the EF factors were associated with baseline emotional reactivity across all structural models (γs $< .15$, *p*s $> .12$). In contrast, consistent with the findings from Models 2 and 5, the relations of reappraisal ability with inhibition and common EF were significant (γs $> .26$, *p*s $< .002$). The pattern of findings remained unchanged when covariates were included in the structural models. Together, these results indicate that common EF is associated with reappraisal ability but not baseline emotional reactivity.

Discussion

Our study yields several notable outcomes. First, we found that the shared, rather than unique, variance among EF processes (i.e., common EF) was positively associated with reappraisal ability. Results from the three-factor EF model showed that when all three EF constituents were assessed simultaneously and their shared variance was partialed out, none of the EF constituents was uniquely related to reappraisal ability. However, when EF was conceptualized as the nested-factor model (Friedman & Miyake, 2017), the common EF component was significantly related to reappraisal ability. Further, the link between common EF and reappraisal held true when covariates—that is, intelligence, gender, depressive symptoms, age, and social desirability—were controlled for, thereby ruling out alternative third-variable effects. Pivotally, our results suggest that the previously reported associations of working memory, inhibition, and shifting with reappraisal ability (Malooly et al., 2013; McRae, Jacobs, et al., 2012; Pe, Raes, Koval, et al., 2013; Schmeichel & Tang, 2014) may instead be driven by a common EF component. Specifically, we speculate that common EF may aid in selecting and activating desired situational narratives and resisting interference from competing, unwanted appraisals or environmental distractors. Our results converge with recent evidence, which positions common EF as the most vital correlate of various behavioral outcomes. For instance, common EF negatively predicted substance abuse (Gustavson et al., 2017), procrastination (Gustavson et al., 2015), implicit racial bias (Ito et al., 2015), and trait worry (Gustavson et al., 2020). However, these behavioral outcomes were either nonsignificantly or weakly related to other EF components (i.e., working-memory-specific and shifting-specific factors). Consistent with this notion, our findings underscore the integral role common EF plays in reappraisal ability.

Our second notable finding is that the relations between reappraisal ability and EF differed when EF was conceptualized at the latent-variable level relative to the individual-task level. To illustrate, certain aspects of our regression results are consistent with past studies that relied on single-task measures of EF. For instance, the positive relation between operation-span task and reappraisal ability dovetails with findings from previous studies (McRae, Jacobs, et al., 2012; Schmeichel et al., 2008). Further, the positive association between the go/no-go task and reappraisal ability is in line with Tabibnia et al.'s (2011) results based on the stop-signal task, which similarly requires that one refrain from responding to a specific target. Moreover, our finding that the animacy-locomotion task was positively related to reappraisal ability is partially congruent with past findings that document the association of reappraisal ability with neutral and affective variants of the task-switching paradigm (Malooly et al., 2013; McRae, Jacobs, et al., 2012). However, we found that other measures that purportedly assess the same EF components of working memory (i.e., rotation-span and symmetry-span tasks), inhibition (i.e., Stroop task), and shifting (i.e., color-shape and magnitude-parity tasks) did not consistently yield the same pattern of findings. Such discrepancies point to task-impurity problems in EF tasks. Specifically, the positive relation between EF and reappraisal ability found in past studies can potentially be attributed to either common EF or task-specific processes (e.g., processing speed, color discrimination, etc.) that are unrelated to EF. Consequently, reliance on individual EF tasks may lead to specious and potentially misleading relations that do not generalize to other construct-similar EF tasks.

In essence, the different sets of analyses—from the individual-task level to the three-factor and the nested-factor models—represent increasing levels of specificity in isolating the EF component of interest. Notably, at the individual-task level, EF tasks reflect both EF and non-EF processes. At the latent-variable level, our findings from the independent-EF models (Models 1 to 3) demonstrate that only the inhibition, but not working-memory or shifting, latent factor was consistently associated with reappraisal ability. These results suggest that previous positive findings using the operation-span task (e.g., McRae, Jacobs, et al., 2012; Schmeichel et al., 2008) likely reflect the spurious correlation between non-EF processes and reappraisal ability. Likewise, null findings based on the Stroop task (see also McRae, Jacobs, et al., 2012) highlight the fact that task-specific idiosyncrasies—that are likely unrelated to reappraisal ability (e.g., verbal ability; McRae, Jacobs, et al., 2012)—attenuate genuine inhibition-reappraisal-ability relations. Further, although the latent-variable approach minimizes non-EF variance and measurement errors, each latent EF factor comprises both common EF and construct-unique components (e.g., working-memory-specific and shifting-specific factors). Therefore, while the null results from the three-factor model (Model 4) do not support the unique roles of EF factors in reappraisal processes, it is still possible that the shared variance among EF factors (i.e., common EF) may still be coupled with reappraisal. To this end, results from the nested-factor model (Model 5) clarify that common EF, but not working-memory-specific and shifting-specific factors, is linked to reappraisal ability. Crucially, our findings emphasize the value of the latent-variable approach in examining EF-reappraisal relations.

Our third notable finding is that we did not find a meaningful association between EF and reappraisal frequency, in contrast to the results for reappraisal ability. This is consistent with past studies, which tend to report direct relations between working memory and task-based, but not self-reported, measures of reappraisal (McRae, Jacobs, et al., 2012; Pe, Raes, Koval, et al., 2013). Further, reappraisal frequency did not moderate the association between EF and reappraisal ability, which seems to be at odds with the finding that individuals with higher reappraisal frequency have better EF to attenuate negative affect (Cohen et al., 2012). These inconsistent findings could be attributed to construct differences between reappraisal ability and frequency. For instance, the reappraisal task we used in our study assessed competence in downregulating negative affect. Correspondingly, EF would be more closely affiliated with reappraisal ability, which is congruent with findings from neuroimaging studies suggesting that similar brain regions subserve EF and reappraisal ability (e.g., Goldin et al., 2008; Ochsner et al., 2004). In contrast, reappraisal frequency represents the tendency to engage in reappraisal on a regular basis and more strongly taps the motivational aspects of reappraisal that are likely influenced by dispositional variables—such as optimism, self-esteem, and subjective and psychological well-being (Gross & John, 2003)—that may be less relevant to EF. Moreover, while task-based measures of reappraisal ability reflect the downregulation of negative emotions, self-reported reappraisal frequency also captures the upregulation of positive emotions (Gross & John, 2003). This could be another factor that contributes to the divergent relations of EF to reappraisal ability and reappraisal frequency, as well as the low correlation between reappraisal ability and reappraisal frequency. Therefore, further research is needed to ascertain whether the asymmetric associations of EF with reappraisal ability and frequency would hold for task-based reappraisal measures that examine both the upregulation and downregulation of positive and negative emotions, respectively.

Additionally, given that the negatively valenced stimuli used in our reappraisal task may or may not reflect the mild to moderate negative experiences that individuals face in daily functioning, it remains to be seen whether different results would be obtained if reappraisal ability were assessed using more ecologically valid stimuli. Further, given that self-reported measures of reappraisal frequency may be susceptible to reporting bias (Schwarz & Strack, 1999), more work is needed to replicate our findings using experience-sampling methods, which would afford more reliable and accurate estimates of reappraisal frequency.

Last, in light of the ongoing debate regarding the measurement and nature of inhibition tasks (e.g., Draheim et al., 2019; Friedman & Miyake, 2017; Rey-Mermet et al., 2018), results from our additional analyses elucidate how the use of bin scores compare with the more conventional performance index of RT difference scores. Notably, we found that bin scores provide higher reliability, zero-order intercorrelations, and factor coherence than RT difference scores (for more details, see online supplemental materials). Our findings dovetail with Draheim et al. (2019) stance that the use of RT difference scores is problematic and that accuracy scores are preferred in the investigation of individual differences. Indeed, given that bin scores incorporate accuracy scores, we found that that bin scores demonstrated better psychometric properties, particularly within a structural equation modeling context, than RT difference scores. Our results are also consistent with the low intercorrelations and factor loadings among RT-based inhibition tasks, as observed by Rey-Mermet et al. (2018). However, contrary to Rey-Mermet et al.'s argument that inhibition tasks measure highly task-specific interference resolution processes rather than a unitary inhibition construct, our findings show that bin scores exhibit consistent factor loadings and intercorrelations among inhibition tasks, indicating that inhibition can be modeled as a unitary factor. Further, we were unable to model an inhibition-specific factor after the common EF factor was estimated. Therefore, our results are most aligned with Friedman and Miyake (2017) position that there may be "nothing special about inhibition" (p. 5), because inhibition is primarily accounted for by the common EF ability to execute and manage goals. This corroborates neuroscientific and behavioral evidence that successful performance on inhibition tasks is predominantly explained by the general goal-related processes that typify common EF (Chatham et al., 2012; Egner & Hirsch, 2005; Hampshire et al., 2010). Given this, our finding of a positive relation between inhibition and reappraisal ability (Model 2) was likely driven by the common-EF—rather than the inhibition-specific—factor, which was corroborated by the positive association between common EF and reappraisal ability (Model 5).

Our study is not without limitations. First, the correlational nature of our research restricts causal inferences. For instance, while we assume that common EF predicts reappraisal ability, it is plausible that more proficient reappraisal ability instead engenders better EF, given that EF has been shown to be malleable to experiential inputs (Diamond, 2013) and that emotional experiences have been argued to be a vital precursor for EF processes (Inzlicht et al., 2015; Pessoa, 2009). Therefore, longitudinal designs are needed to ascertain the directionality of the relations between EF and reappraisal.

Second, although we posit that task-based and self-reported measures of reappraisal index different constructs, it should be noted that they both involve subjective self-reported ratings of emotional experiences. Therefore, task-based reappraisal measures may still be susceptible to motivational factors and demand characteristics, such as inclinations to follow experimental instructions and social desirability. Although we found that our core results still hold true when social desirability was controlled for (see Table 3), we acknowledge that statistically controlling for self-reported social desirability scores may minimize, but does not completely mitigate, social desirability responding or other demand characteristics. Hence, to more robustly account for demand characteristics and method effects, future research should consider other methods (e.g., psychophysiology, behavioral expressions, etc.) to assess emotional responding.

Third, although we have established common EF as a crucial cognitive correlate of reappraisal, it is unclear which components of cognitive reappraisal—such as generating positive situational narratives and resisting interference from competing negative appraisals—most strongly account for the observed relation. Relatedly, the relatively short reappraisal duration (i.e., 8 s) in our study would more strongly tap implementation processes in the early stages of reappraisal (i.e., selecting from potential alternative reappraisal strategies and resolving conflict from overt behavioral interference; Kalisch, 2009). Therefore, there is a need to determine whether common EF facilitates maintenance/monitoring operations (i.e., sustaining reappraisal thoughts and goals in one's mind, and monitoring the effects of reappraisal strategies on emotional states) that are more prominently implicated in the later stages of reappraisal. To this end, future work should use mood-induction procedures (e.g., anticipation of pain; Kalisch, 2009) that are more suited to capture the maintenance/monitoring processes in late reappraisal. Further, it remains to be seen whether common EF would be differentially related to detached (i.e., thinking about the situation in nonemotional ways) and positive (i.e., positively reframing negative features of the event) reappraisal strategies. Indeed, there is some evidence that performance on EF measures is related to detached but not positive reappraisal (Liang et al., 2017) in older adults. Accordingly, identifying the specific components of reappraisal processes and the types of reappraisal strategies that are most closely associated with common EF is an important future direction.

Relatedly, because our results only speak to EF and reappraisal processes, it remains to be seen how the unity/diversity model of EF could be implicated in other emotion-regulation strategies. For instance, prior work has identified the potential role of EF in ruminative tendencies (Altamirano et al., 2010) and expressive suppression (von Hippel & Gonsalkorale, 2005). However, given that these findings have only been established at the individual-task level, future research should ascertain whether such associations would hold at the latent-variable level.

Fourth, because our sample comprised undergraduate students, our findings may not be generalizable to other age groups. Notably, the structure of EF has been shown to vary for different age groups, with the nested-factor and one-factor models being most reflective of young adults and adolescent/child samples, respectively (Karr et al., 2018). Moreover, past research has documented developmental differences in reappraisal efficiency, whereby the activation of EF-related prefrontal brain regions increases linearly with advancing age (McRae, Gross, et al., 2012). Further, the relatively homogeneous nature of our college sample likely resulted in the diminished reliability observed in some of our EF tasks (e.g., symmetry span) relative to those reported in past studies (e.g., Foster et al., 2015). However, it should be noted that we took steps to minimize issues related to reliability, such as the use of (a) bin scores, which addresses the low internal consistency of difference scores, and (b) latent-variable analysis, which corrects for measurement errors and results in disattenuated path coefficients and latent-factor correlations with corresponding adjustments in standard errors (Hedge et al., 2018). Nevertheless, future work should extend our findings to more heterogeneous samples, such as noncollege samples from other age groups (e.g., adolescents and older adults).

Fifth, while our sample size was sufficiently powered in detecting medium effect sizes and is larger than most studies in the literature on EF and emotion regulation (e.g., Schmeichel et al., 2008; Tabibnia et al., 2011), it may still lack statistical power for small effect sizes, as seen in some studies (e.g., McRae, Jacobs, et al., 2012). This could potentially account for the some of our null findings, particularly for the associations between the three-factor model and reappraisal ability and frequency. Additionally, in terms of correlational stability based on our medium effect sizes (e.g., $\gamma = .29$ for the relation between common EF and reappraisal ability), our sample size fulfils the minimum criteria for effect size fluctuations (i.e., corridor of stability) of $\pm.15$ ($n > 78$) and $\pm.20$ ($n > 43$), but not for $\pm.10$ ($n > 181$), around rs = .30 to .40 at 80% power (Schönbrodt & Perugini, 2013). Although an effect size fluctuation of $\pm.10$ was recommended, it should be noted that the desired level of effect size fluctuation is dependent on specific research contexts (Schönbrodt & Perugini, 2013). To our knowledge, there are no established norms for acceptable effect size fluctuations within the EF and emotion-regulation literature. Accordingly, further studies with larger sample sizes are needed to more definitively ascertain the EF-reappraisal link, and more research is needed to ascertain optimal effect size fluctuations in the determination of sample sizes for future endeavors.

To reiterate, the key strengths of our study include the comprehensive assessment of various EF facets and reappraisal processes (i.e., ability and frequency) and use of the latent-variable approach to address the task-impurity problem in EF tasks. Theoretically, our findings show that EF components do not play unique roles in reappraisal processes; rather, it is the common EF component—a general goal-management ability that is required in all types of EF—that is concomitant with the ability to reappraise negative experiences. Methodologically, our results highlight that disparate conclusions may be drawn when EF is assessed at the individual-task level and, therefore, reinforce the need to measure EF using multiple tasks at the latent-variable level. In essence, our findings provide crucial theoretical, methodological, and empirical insights into how EF is associated with reappraisal.

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Appendix A

Zero-Order Correlations Between Variables of Interest

Table A1

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1. Anti	—																									
2. G/NG	**.31**	—																								
3. Stroop	**.31**	**.33**	—																							
4. OS	**.29**	**.16**	.12	—																						
5. RS	**.30**	.13	**.20**	**.45**	—																					
6. SS	.14	**.16**	.11	**.32**	**.58**	—																				
7. CS	**.29**	**.33**	**.36**	**.22**	**.22**	**.25**	—																			
8. AL	**.24**	**.42**	**.39**	**.23**	**.36**	**.22**	**.53**	—																		
9. MP	**.24**	**.35**	**.25**	**.19**	**.30**	**.19**	**.59**	**.60**	—																	
10. RF-1	−.10	−.05	.03	.01	.03	−.05	.13	.05	.01	—																
11. RF-2	−.01	.02	.08	.03	.05	−.14	.11	.03	.06	**.58**	—															
12. RF-3	.01	−.04	.10	.01	.06	.01	.04	.05	.01	.14	**.28**	—														
13. RF-4	−.03	.04	.06	−.03	−.02	−.07	.14	.05	.05	**.51**	**.53**	**.43**	—													
14. RF-5	.04	.06	.14	−.03	.07	−.02	**.17**	.04	.09	**.41**	**.47**	**.42**	**.75**	—												
15. RF-6	.04	.04	.07	.01	.05	−.04	**.16**	.05	.09	**.40**	**.55**	**.49**	**.78**	**.81**	—											
16. RA-D-P1	.14	**.24**	**.18**	**.16**	.12	.05	.14	**.20**	.10	−.07	.01	.10	.04	.01	.05	—										
17. RA-D-P2	**.18**	**.19**	**.17**	**.16**	.10	.06	.12	**.21**	.12	.01	.12	**.18**	.07	.13	**.17**	**.71**	—									
18. RA-D-P3	**.20**	.14	.07	.12	.11	−.01	.13	**.16**	.05	−.04	.06	.13	.08	.10	.09	**.61**	**.72**	—								
19. RA-L-P1	−.01	.07	.13	−.03	.06	.01	−.02	.04	.02	−.03	.01	.10	.01	.06	.05	**.51**	**.49**	**.38**	—							
20. RA-L-P2	.08	.08	**.18**	.09	**.16**	.14	.13	**.15**	.12	−.11	−.02	.06	−.02	.06	.07	**.55**	**.52**	**.41**	**.66**	—						
21. RA-L-P3	.02	.04	.07	−.07	.11	.07	.02	.11	.03	**−.18**	−.07	.08	−.05	−.02	.01	**.48**	**.54**	**.42**	**.67**	**.68**	v					
22. RSPM	**.38**	**.17**	**.19**	**.33**	**.32**	**.26**	**.24**	**.31**	**.27**	.01	−.04	.10	−.02	.07	.02	.13	.11	.05	−.05	.11	.10	—				
23. CES-D-10	−.07	−.08	−.04	−.06	−.02	.00	−.09	−.04	.01	−.08	−.10	−.09	−.12	**−.16**	−.14	**−.21**	−.11	−.10	−.02	−.03	.01	−.06	—			
24. Gender	**.17**	.15	.00	.09	.09	.07	−.06	.06	−.03	.11	.09	.11	.07	.04	.04	**.24**	**.21**	**.19**	**.25**	.14	.10	.12	.05	v		
25. Age	.08	.11	.03	.06	.08	.11	.01	.06	.01	−.02	.05	.07	.10	.08	.10	**.21**	**.16**	**.16**	**.34**	**.27**	**.25**	.03	.01	**.58**	—	
26. Education	.13	.08	.09	.07	.14	.04	.02	.10	.06	.02	.08	.11	**.16**	.14	**.19**	**.16**	.12	.12	.13	**.19**	**.18**	.03	−.01	**.19**	**.55**	—
27. SD	.04	−.01	.03	.05	.06	.02	.02	.05	.01	**−.18**	**−.22**	−.13	**−.24**	**−.18**	**−.27**	.12	.03	.07	.03	.07	.07	.02	.07	.05	.03	.06

Note. Anti = antisaccade; G/NG = go/no-go; OS = operation span; RS = rotation span; SS = symmetry span; CS = color shape; AL = animacy locomotion; MP = magnitude parity; RF-1 – RF-6 = reappraisal frequency subscale items 1 to 6 from the Emotion Regulation Questionnaire; RA-D = reappraisal ability “Decrease Negative” trials; RA-L = reappraisal ability “Look Negative” trials; P1 – P3 = parcels 1 to 3; RSPM = Raven’s Standard Progressive Matrices Short-Form; CES-D-10 = Center for Epidemiological Studies-Depression 10-item short form; SD = social desirability as indexed by the impression management subscale of the Balanced Inventory of Desirable Responding-Short Form. Gender was coded as 0 = *female*, 1 = *male*. Significant correlations marked in boldface, $p < .05$.

(*Appendices continue*)

Appendix B

Model Fit Indices, Factor Loadings, and Parameter Estimates for Additional Analyses

Table B1

Fit Indices for the Three-Factor and Nested-Factor Measurement Models

Model	χ^2	*df*	χ^2/df	RMSEA	SRMR	CFI
Three-factor model						
RT difference scores	43.23	24	1.80	.069	.057	.898
LISAS difference scores	50.28	24	2.10	.080	.061	.871
Bin scores	37.88	24	1.58	.068	.042	.965
Nested-factor model						
RT difference scores	38.28	21	1.82	.070	.052	.909
LISAS difference scores	44.86	21	2.14	.082	.056	.883
Bin scores	33.24	21	1.58	.059	.039	.969

Note. WM = working memory; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual; CFI = comparative fit index; RT = reaction time; LISAS = linear integrated speed-accuracy score.

Table B2

Standardized Factor Loadings for the Three-Factor Measurement Model Using Confirmatory Factor Analysis

	RT difference scores			LISAS difference scores			Bin scores		
Measure	Inhibition	WM	Shifting	Inhibition	WM	Shifting	Inhibition	WM	Shifting
Stroop	**.21**	—	—	**.31**	—	—	**.57**	—	—
Antisaccade	**.80**	—	—	**.73**	—	—	**.51**	—	—
Go/no-go	**.40**	—	—	**.42**	—	—	**.61**	—	—
Operation span	—	**.53**	—	—	**.53**	—	—	**.54**	—
Rotation span	—	**.90**	—	—	**.90**	—	—	**.88**	—
Symmetry span	—	**.64**	—	—	**.64**	—	—	**.66**	—
Color shape	—	—	**.36**	—	—	**.52**	—	—	**.72**
Animacy locomotion	—	—	**.44**	—	—	**.46**	—	—	**.78**
Magnitude parity	—	—	**.70**	—	—	**.52**	—	—	**.77**

Note. RT = reaction time; LISAS = linear integrated speed-accuracy score; WM = working memory. All values were reverse scored such that higher values reflect better performance. All factor loadings (in boldface) were statistically significant, $p < .05$.

(*Appendices continue*)

Table B3

Standardized Factor Loadings of the Nested-Factor Measurement Model Using Confirmatory Factor Analysis

	RT difference scores			LISAS difference scores			Bin scores		
Measure	CEF	WM	Shifting	CEF	WM	Shifting	CEF	WM	Shifting
Stroop	**.22**	—	—	**.31**	—	—	**.56**	—	—
Antisaccade	**.77**	—	—	**.74**	—	—	**.50**	—	—
Go/no-go	**.40**	—	—	**.41**	—	—	**.58**	—	—
Operation span	**.36**	**.42**	—	**.35**	**.42**	—	**.34**	**.41**	—
Rotation span	**.40**	**.77**	—	**.40**	**.77**	—	**.42**	**.78**	—
Symmetry span	.19	**.65**	—	.19	**.65**	—	**.30**	**.58**	—
Color shape	.08	—	**.33**	**.22**	—	**.43**	**.60**	—	**.37**
Animacy locomotion	.16	—	**.36**	**.23**	—	**.37**	**.68**	—	**.33**
Magnitude parity	.11	—	**.81**	.14	—	**.59**	**.55**	—	**.71**

Note. RT = reaction time; LISAS = linear integrated speed-accuracy score; CEF = common executive function; WM = working memory. All scores were reverse coded such that higher values reflect better performance. Significant factor loadings are marked in boldface, $p < .05$.

Table B4

Standardized Parameter Estimates for the Independent-EF Factors and the Three-Factor Models

	Unadjusted model		Adjusted model with covariates	
Model	Reappraisal ability	Reappraisal frequency	Reappraisal ability	Reappraisal frequency
Independent-EF factors				
RT difference scores				
Inhibition	**.30 (.09)**	.08 (.11)	**.24 (.11)**	.05 (.12)
Shifting	.01 (.10)	.11 (.11)	.08 (.10)	.12 (.11)
LISAS difference scores				
Inhibition	**.29 (.09)**	.09 (.11)	**.24 (.11)**	.05 (.12)
Shifting	.13 (.10)	.14 (.11)	.17 (.09)	.13 (.11)
Bin scores				
Inhibition	**.27 (.08)**	.09 (.11)	**.27 (.10)**	.05 (.13)
Shifting	**.15 (.07)**	.13 (.09)	.15 (.08)	.14 (.09)
Three-factor model				
RT difference scores				
Working memory	−.07 (.09)	−.01 (.11)	−.03 (.09)	−.01 (.11)
Inhibition	**.30 (.12)**	.04 (.13)	.23 (.12)	.02 (.13)
Shifting	−.01 (.10)	.11 (.11)	.02 (.10)	.10 (.11)
LISAS difference scores				
Working memory	−.06 (.09)	−.01 (.11)	−.04 (.09)	−.02 (.11)
Inhibition	**.28 (.12)**	.02 (.15)	.19 (.14)	−.01 (.16)
Shifting	.04 (.12)	.13 (.13)	.10 (.12)	.13 (.14)
Bin scores				
Working memory	−.04 (.09)	−.05 (.11)	−.04 (.09)	−.06 (.11)
Inhibition	.36 (.18)	−.01 (.21)	.30 (.19)	−.06 (.22)
Shifting	−.10 (.17)	.16 (.20)	−.04 (.17)	.20 (.20)

Note. RT = reaction time; EF = executive function; LISAS = linear integrated speed-accuracy score; RT and LISAS scores are applicable to inhibition and shifting factors, since working-memory tasks are solely indexed by accuracy scores. For the independent-EF models, each EF dimension was assessed individually; for the three-factor model, all three EF factors were examined simultaneously. Parameter estimates for covariates (i.e., intelligence, gender, depressive symptoms, age, and social desirability) are not shown for brevity. Standard errors are shown in parentheses. Significant values are marked in boldface, $p < .05$.