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Abstract

Cognitive reappraisal is an adaptive emotion regulation strategy that positively impacts various facets of adaptive functioning (e.g., interpersonal relations, subjective well-being). Although reappraisal implicates cognitive processing, a clear consensus concerning the cognitive underpinnings of reappraisal has not yet been reached. Therefore, we examined how executive function (EF)—i.e., three general-purpose control abilities comprising working memory, inhibition, and shifting—are associated with performance-based reappraisal ability and self-reported reappraisal frequency. Using a latent-variable approach, we found that the shared variance among EF tasks (i.e., common EF)—a general goal-management ability that facilitates the active maintenance of task goals—significantly predicted reappraisal ability, but not reappraisal frequency. However, the three EF components did not uniquely predict reappraisal ability and frequency. Further, when EF was conceptualised at the individual-task level, we found inconsistent patterns of associations of EF constituents with reappraisal, thereby underscoring the need to measure all aspects of EF using multiple indicators at the latent-variable level. In essence, our findings provide vital theoretical, methodological, and empirical advancements towards a better understanding of the cognitive mechanisms underlying reappraisal.

Keywords: reappraisal, emotion regulation, executive function, working memory, inhibition, shifting, common EF

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Introduction

Cognitive reappraisal (hereinafter *reappraisal*) is an effective emotion regulation strategy that serves to downregulate undesired emotions (Gross, 2008; Gross & John, 2003) through a deliberate effort to reinterpret an emotion-eliciting event to attenuate its emotional impact. Individuals who use reappraisal more frequently have been reported to experience closer interpersonal relations, lower depressive symptomology, as well as higher levels of psychological and subjective well-being (Garnefski, Kraaij, & Spinhoven, 2001; Gross & John, 2003; John & Gross, 2004; McRae, Jacobs, Ray, John, & Gross, 2012). Given the critical importance of reappraisal in a myriad of adaptive functioning, an increasing number of studies have attempted to identify individual differences in higher-order cognitive control abilities—i.e., executive function (EF), a collection of general-purpose control processes—that underlie reappraisal (for a review, see Schmeichel & Tang, 2015). Accumulated empirical evidence corroborates the role of EF during reappraisal processes. However, a clear consensus concerning the predictability of the multifaceted construct of EF—which involves inhibition, updating, and shifting (Miyake et al., 2000)—on reappraisal has not yet emerged. Further, it still remains to be seen whether reappraisal ability and reappraisal frequency would have similar cognitive underpinnings. In light of these issues, we sought to investigate how the shared variances among EF components and unique variance of each EF component are related to reappraisal ability and frequency, using a rigorous method, i.e., a latent variable approach.

The theoretical construct of EF

A well-established theoretical conceptualisation 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 (hereinafter *working memory*) is defined as the ability to retain, monitor, and manipulate goal-relevant information within a mental work space in the presence of alternative goals or other distractions (Engle & Kane, 2004). Inhibition reflects the ability to suppress prepotent responses and task-irrelevant information in order to sustain task-relevant goals (Friedman & Miyake, 2004). Shifting denotes 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 common variance shared across all EF abilities (i.e., common EF denoting the unity aspect) and unique variances attributed to working memory- and shifting-specific factors (i.e., diversity) that account for the remaining variance between working memory and shifting tasks, respectively, after common variance has been extracted (Miyake & Friedman, 2012). In this new model, there is no more unique variance left for inhibition as it is completely subsumed under the common EF factor, which reflects the general ability to 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 the inhibition-specific factor can be accounted for by the fact that the ability to monitor and execute goals, as captured by the common EF factor, is an essential requirement for successful performance on all types of EF measures, and particularly so for inhibition tasks (Friedman & Miyake, 2017). Moreover, recent neuropsychological evidence has highlighted that performance on inhibition tasks is primarily driven by the general goal-management abilities that are representative of common EF (Banich & Depue, 2015; Chatham et al., 2012; Hampshire, Chamberlain, Monti, Duncan, & Owen, 2010; Munakata et al., 2011), thereby underscoring the centrality of common EF in explaining inhibition operations. Accordingly, common EF has been evidenced to be a precursor for effective performance on all types of EF and other crucial cognitive abilities, such as fluid intelligence (Friedman et al., 2008) and language skills (Gooch, Thompson, Nash, Snowling, & Hulme, 2016), as well as various everyday behavioural outcomes, such as behavioural disinhibition (Herd et al., 2014), self-control (Friedman, Miyake, Robinson, & Hewitt, 2011), substance abuse (Gustavson et al., 2017), procrastination (Gustavson, Miyake, Hewitt, & Friedman, 2015), implicit racial bias, and trait worry (Gustavson et al., 2019).

The relations between EF and reappraisal

Extant evidence has alluded that reappraisal relies, in part, on EF which is crucial for regulating various day-to-day processes (e.g., physical health, marital harmony, job satisfaction; Diamond, 2013). For instance, neuroimaging studies suggest that similar brain regions are involved in both reappraisal and EF (Ochsner & Gross, 2005). Specifically, the ability to reappraise (i.e., thinking objectively to decrease emotional reactivity) negatively valenced stimuli (e.g., evocative pictures) is concomitant with (a) the increased activation of the dorsolateral and ventrolateral prefrontal regions, which are also implicated in EF processes, and (b) the reduced activation of emotion-related regions, such as the amygdala and insula (Banks, Eddy, Angstadt, Nathan, & Phan, 2007; Drabant, McRae, Manuck, Hariri, & Gross, 2009; Goldin, McRae, Ramel, & Gross, 2008; Kim & Hamann, 2007; Lévesque et al., 2003; Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner et al., 2004). Given these findings supporting the notion that reappraisal and EF are based on similar neural substrates, a growing body of research has demonstrated a close relation between each EF component (working memory, inhibition, and shifting) with reappraisal.

Working memory. Findings from several empirical studies have shown the contribution of working memory towards reappraisal. Notably, during reappraisal, working memory has been posited to aid in the gating and manipulation of alternative narratives within one's mental workspace by sustaining goal-relevant appraisals (Schmeichel & Tang, 2014). For instance, in a study by Schmeichel, Volokhov, and Demaree (2008), participants completed a working memory measure (i.e., 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. (2008) 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, thereby demonstrating that working memory facilitates the regulation of negatively valenced stimuli through reappraisal.

Another study by McRae et al. (2012) looked at how various cognitive abilities—i.e., inhibition, shifting, verbal ability, abstract reasoning and working memory (as assessed by the operation span task)—are related to 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 affectivity among individuals with higher, but not for those with lower, levels of working memory (assessed by the emotional *n*-back task). Therefore, the aforementioned findings highlight that working memory underlies the reappraisal of negative experiences.

Inhibition. Empirical evidence has also lent support to the association between inhibition and reappraisal. Inhibition has been posited to aid reappraisal through the suppression of undesired appraisals of situations in service of desired reappraisals (Schmeichel & Tang, 2014). For example, Tabibnia et al. (2011) compared differences in inhibition (assessed by the stop-signal task) and reappraisal ability (i.e., reinterpret evocative pictures in non-negative 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, Turnbull, and Gross (2014) reported that individuals with focal damage to left fronto-parietal regions, relative to healthy controls, demonstrated markedly greater difficulties in inhibition and spontaneous reappraisal generation (i.e., producing as many positive aspects of the negatively valenced situations as possible), thereby highlighting 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. However, disconfirming evidence has been obtained from McRae et al.'s (2012) study, which showed null relations between reappraisal ability (i.e., to reinterpret negatively valenced stimuli objectively) and inhibition (assessed by the Stroop task). Therefore, although the literature suggests that inhibition is likely implicated in reappraisal, the equivocal evidence warrants further investigations.

Shifting. While shifting has been hypothesized to assist in the flexible switching from a negative appraisal to a more desirable narrative (Schmeichel & Tang, 2014), the empirical evidence is noticeably scarce (see also Schmeichel & Tang, 2014). For example, Malooly, Genet, and Siemer (2013) inquired if reappraisal ability (i.e., adopting an objective mindset while viewing aversive film clips) would be related to performance on an affective shifting measure, where participants had to sort a given picture according to affective (i.e., negative or positive) and nonaffective (i.e., one or fewer human beings, or two or more human beings) task sets. Results indicated that higher reappraisal ability was associated with the faster switching (i.e., lower switch costs) from affective to nonaffective task sets for negative images as well as the faster switching from nonaffective to affective task sets for positive images. These findings imply that the ability to shift away from negative aspects, as well as towards the positive features, of emotional material predicts reappraisal of negative emotions. In contrast, another study by McRae et al. (2012) showed that better reappraisal ability was concomitant with more accurate, but slower, shifting performance (assessed by the global/local task), thereby signifying a speed-accuracy tradeoff. Collectively, the cumulative evidence highlights that reappraisal implicates working memory and inhibition, albeit with equivocal findings for the latter. 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 exist several notable limitations. First, previous studies have independently examined the relations 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) toward reappraisal remains undetermined. For instance, efficient performance on working memory measures, such as the operation span task, requires (a) the inhibition of task-irrelevant processes (i.e., solving arithmetic problems) interfering with task-relevant information (i.e., to-be-remembered items) and (b) shifting between the distractor and memory tasks (Draheim, Hicks, & Engle, 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, Meyer, & Evans, 2001). Hence, it is vital to concurrently examine the three facets of EF in a single study to shed light on the unique contribution of each EF constituent.

More importantly, while extant theories have detailed the unique roles of each EF in reappraisal (Schmeichel & Tang, 2014), it is plausible that reappraisal success may be driven by the shared variance among EF constituents (i.e., common EF) instead. Specifically, common EF may be implicated in the active maintenance of the goal to reappraise by sustaining goal-relevant positive narratives in one's mind, while resisting interference from conflicting negative situational appraisals, as well as monitoring how successfully one's emotional state has been altered. Crucially, it is not clear whether the previously established positive findings between each EF factor with reappraisal reflects variance shared across all EF processes or unique variance from specific EF components (i.e., working memory or shifting). To this end, more work is required to disentangle the extent to which the shared and unique aspects of EF predict reappraisal.

A second limitation of past research is the reliance on single-task EF measures (e.g., McRae 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 issue as EF tasks tend to additionally tap other task-specific non-EF abilities (Foster et al., 2015; Miyake et al., 2000). Notably, previous studies have evidenced low, and often statistically nonsignificant, correlations among EF tasks (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 needed 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 colours. Crucially, on 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 handful of studies did not find direct relations between reappraisal ability with EF (McRae 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 the current research are as follows. First, given that previous studies that have explored the relations between reappraisal and each EF component independently (Schmeichel & Tang, 2014), we drew on the three-factor (inhibition, working memory, and shifting) and nested-factor (i.e., common EF, working memory, and shifting) models to investigate the contributions of EF constituents in predicting reappraisal. As the three-factor model partials out the common variance among EF tasks, it allows for the investigation of the unique relations of each EF component with reappraisal. On the other hand, the nested-factor model affords the simultaneous assessment of the contributions of both the shared variance among EF processes (i.e., common EF) and unique variances of working memory and shifting toward reappraisal processes.

Second, to address the task-impurity problem associated with EF tasks, a latent-variable approach was employed 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 among EF tasks (Miyake et al., 2000). Therefore, we sought to examine how our findings would differ when EF was modelled at the latent-variable level, relative to the individual-task level.

Third, we assessed how EF would be related to self-reported and performance-based measures of reappraisal, which are two commonly employed indices of reappraisal in past research (e.g., McRae et al., 2012; Pe, Raes, Koval, et al., 2013). Notably, the two measures of reappraisal are not analogous (McRae, 2013). While self-reports signify reappraisal frequency, performance-based tasks characterise reappraisal ability or success. Given that similar neural substrates are 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 be necessarily 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 of EF and reappraisal was not confounded by third variable effects, we controlled for crucial covariates—such as intelligence, gender, depression—that have been shown to affect either EF or reappraisal (Arffa, 2007; Ehring, Tuschen-Caffier, Schnülle, Fischer, & Gross, 2010; McRae et al., 2012; McDermott & Ebmeier, 2009; Nolen-Hoeksema & Aldao, 2011; Urbanek et al., 2009).

Fourth, we examined whether reappraisal frequency could moderate the associations between EF and reappraisal ability. A previous study by Cohen, Henik, and Moyal (2012) showed that while negatively valenced stimuli interfered with inhibitory control (assessed by the flanker task), this emotional interference effect was reduced for individuals who more frequently use reappraisal than do those who employ reappraisal less frequently. This finding suggests that more frequent use of reappraisal is concomitant with an improved inhibition ability to attenuate undesired negative affect driven by negative material. Therefore, we inquired if the relations of EF with reappraisal ability would be stronger for individuals who use 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 credits or monetary reward ($30). This sample size is comparable with past studies that have used multiple measures to assess each EF component (e.g., Miyake et al., 2000; Unsworth et al., 2014). Moreover, for a structural equation model with a maximum of six latent variables and 24 manifest variables (see Results), a minimum sample size of 161 is required to detect a medium effect size of .30 (Soper, 2018), which is consistent with the effect sizes reported in previous studies (e.g., McRae et al., 2012; Schmeichel et al., 2008). Given that the data for the current research constitute a subset of a larger database, only variables relevant to the study's hypotheses were reported (see Table 1 for descriptive statistics).

Table 1

Descriptive Statistics of Predictors, Covariates, and Criterion Variables

	M	*SD*	Min	Max	Skewness	Kurtosis	Reliability[1]
Predictors							
Executive function (EF)[2]							
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[3]	14.18	1.92	1.29	16.19	-2.57	11.37	.79
Shifting							
Colour-shape[3]	14.20	1.90	3.24	17.19	-2.70	12.50	.80
Animacy-locomotion[3]	13.94	2.01	4.17	17.32	-1.90	5.77	.89

Magnitude-parity[3]	13.43	2.09	3.39	17.24	-1.36	3.52	.86
Covariates							
Gender (% female)[4]	66.3	-	-	-	-	-	-
Depressive symptomology	2.07	0.54	1.00	3.80	0.62	0.12	.67
Fluid intelligence	6.41	1.93	0.00	9.00	-0.77	0.25	.67
Criterion							
Reappraisal frequency	4.62	0.99	2.33	7.00	-0.20	-0.38	.86
Reappraisal ability							
Reappraisal trials[5]	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[5]	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	-

Note. [1] For the following EF tasks, reliability estimates were calculated using Spearman-Brown adjusted split-half correlations: Stroop, colour-shape, animacy-locomotion, and magnitude-parity tasks. For all other measures, reliability estimates were computed based on Cronbach's alpha.
[2] Due to administrative and technical errors, there were missing data for the following EF tasks: antisaccade task (n = 1), go/no-go task (n = 1), operation span (n = 1), symmetry span (n = 1), Stroop task (n = 4), animacy-locomotion task (n =1), and magnitude-parity task (n = 2).
[3] For Stroop, colour-shape, animacy-locomotion, and magnitude-parity tasks, average bin scores were reverse-coded such that higher values denote better performance.
[4] Gender was coded as 0 = *female*, 1 = *male*.
[5] Responses for the reappraisal task were reverse-coded such that higher values indicate higher levels of reappraisal ability.

Materials

Reappraisal frequency. The 6-item reappraisal subscale of the Emotion Regulation Questionnaire (Gross & John, 2003) was adapted to index the frequency in which cognitive reappraisal was employed 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 et al. (2012) was implemented.[1] Participants viewed a series of pictures and had to either (i) 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 (ii) reappraise the pictures 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 coloured frames—which served to remind participants what they were supposed to do—was shown (7 s). Green and blue frames were paired with "Look" and "Decrease" instructions, respectively. Subsequently, participants responded to the question "How negative do you feel?" (4 s) on a 5-point scale (1 = *not at all*, 5 = *very negative*). Thereafter, an intertrial interval with the instruction "Relax" was shown (7 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 degree of reappraisal. Higher values for the "Decrease Negative" condition, relative to the "Look Negative" condition, indicated better reappraisal ability.

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

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. Scores for the reappraisal trials were significantly higher than those for the baseline trials, $t(169) = 11.98$, $p < .001$, denoting that the negative pictures were rated as less negative on the reappraisal trials than on the baseline trials. At the end of the reappraisal task, we administrated an open-ended funnel questionnaire inquiring the types of strategies that participants used during the task. We found that the most predominant strategies used were related to reappraisal (e.g., thinking that the situation would improve for the better), rather than other non-reappraisal strategies (e.g., not looking at the screen).

Working memory. We adapted three complex span measures (Foster et al., 2015) to measure working memory capacity. These measures consisted of distractor and memory (i.e., encoding to-be-remembered items) tasks. 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 task. In the distractor task, participants verified whether a given arithmetic problem (e.g., (2 x 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, that trial was counted as an error. Thereafter, a letter to be encoded was presented on 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 4x3 matrix of letters, participants were directed to recall and click the appropriate letters in the correct order. The matrix remained on screen until the participant’s response was submitted.

Prior to the main test, a series of practice trials were presented. First, participants were shown four trials requiring 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. Lastly, they completed three trials of set size two that contained both math problem 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 task. Similarly, participants were presented with a distractor task, wherein 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. Thereafter, participants were directed 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 sequence (i.e., set size) varied from two to five per trial. All other aspects were identical to the operation span task.

Symmetry span task. As a distractor task, participants indicated whether a geometric figure was symmetrical along its vertical axis. Next, they were asked to remember the locations of red squares on a 4x4 grid. During recall, upon the presentation of the same 4x4 grid (without the red squares), participants indicated the positions of the previously presented red squares in the correct order. The set size varied from two to five per trial and was randomised across two blocks of trials. All other methodological aspects were identical to other complex span tasks.

Inhibition. Three measures were employed to tap the inhibition of prepotent responses, which relates to the ability to deliberately suppress dominant or automatic responses (Friedman & Miyake, 2004).

Antisaccade task. 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 is 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 centre of the screen for a variable amount of time (one of six times from 200 ms to 2,200 ms with 400 ms intervals). A visual cue ("=") was flashed either to the left or to the 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 appeared, followed by the target stimulus, which was positioned 11.33° the left or right from 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 in the opposite sides on the screen (i.e., when the flashing cue appeared on the left side of the screen, the target appeared on the right and vice versa). Participants completed 24 practice trials, followed by 72 main test trials. As 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, whereby higher scores represented better performance.

Go/no-go task. Adapted from Redick, Calvo, Gay, and Engle (2011), 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 withhold from responding when the target *X* letter was shown (i.e., no-go trials). In every trial, a letter stimulus was first presented for 300 ms, followed by a blank screen which lasted for 700 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 task. Adapted from Unsworth and McMillan (2014), participants had to identify the colour of a word instead of reading the word (e.g., blue printed in red ink). In each trial, participants saw a fixation point (500 ms), followed by the target word, whereby participants had to indicate, as quickly and accurately as possible, the colour of the target word by pressing the *R* (red), *Y* (yellow), *G* (green), or *B* (blue) keys. The target word remained on the screen until a response key was entered. Subsequently, a blank screen, which served as the intertrial interval, was shown for 1,000 ms. Two types of trials were randomly presented: (a) 144 congruent trials with the target word printed in the same colour as the word (e.g., green printed in green ink), (b) 72 incongruent trials with the target word printed in a different colour (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. Prior to 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 the efficiency in shifting back and forth between multiple mental sets (Monsell, 2003). The dependent measure for all three measures was reverse-coded bin scores, wherein higher scores denoted better shifting abilities (see Binning Procedure).

Colour-shape task. Participants sorted bivalent figures (i.e., green circle or red triangle) based on the colour 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 colour rule was a colour gradient and the cue for the shape rule was a row of black squares. In every trial, a fixation point (350 ms) followed by a black screen (150 ms) was first presented. The cue was then shown and, after a delay (250 ms), the target was presented. The cue and target remained on the screen until a response was given. The intertrial interval, signified by a blank screen, was 850 ms. There were four blocks (36 trials each) that comprised an equal number of switch trials (e.g., shape rule followed by colour rule) and repeat trials (e.g., colour rule for two consecutive trials), and the first trial in each block was excluded. The trial order was randomised, and the maximum number of consecutive repeat trials was set at four. There were 70 switch trials and 70 repeat trials.

Magnitude-parity task. 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 colour-shape task.

Animacy-locomotion task. 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 and skies, respectively. All other methodological aspects were identical to other shifting tasks.

Covariates. Fluid intelligence was assessed by a 9-item short form of the Raven's Standard Progressive Matrices (RSPM-SF; Bilker et al., 2012). Participants saw a series of geometric designs, each with a missing segment. They 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 symptomology (in the past week) was indexed by a 10-item short form of the Center for Epidemiological Studies-Depression survey (CES-D-10; Andresen, Malmgren, Carter, & Patrick, 1994) based on a 4-point scale (1 = *rarely or none of the time*, 4 = *most of the time*). Demographic information was obtained using a background questionnaire.

Binning Procedure. Given that bin scores have been shown to proffer better reliability, validity, and sensitivity in the detection of larger effect sizes than do pure RT or accuracy scores (Draheim, Hicks, & Engle, 2016; Hughes, Linck, Bowles, Koeth, & Bunting, 2014), we used bin scores to index inhibition costs in the Stroop task and switching efficiency in 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 repeat trials was subtracted from the RT of every accurate switch trial; for the Stroop task, the mean RT of 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 containing 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 one-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 task, colour-shape task, antisaccade task, and rotation span task. 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 task, go/no-go task, symmetry span task, animacy-locomotion task, and Stroop task. Last, participants finished several questionnaires that included the CES-D-10 (i.e., depressive symptomology). 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 individual performance to be directly comparable. The entire study lasted approximately three hours.

Results

Analysis plan

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

Reappraisal ability and frequency were modelled as endogenous latent variables. For the latent variable of reappraisal ability, indicators were generated by parcelling, 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, Cunningham, Shahar, & Widaman, 2002). Specifically, the latent variable of reappraisal ability was formed based on three parcelled indicators driven from responses on all "Decrease Negative" trials. To control for baseline ratings without reappraisal for negatively valenced images, the latent variable of baseline control was generated by three parcelled indicators from responses on the "Look Negative" trials. For the latent variable of reappraisal frequency, the indicators were responses from the six items of 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 modelling was performed to examine the links between EF and reappraisal processes. In particular, we examined the unique relations between the various elements of the three-factor EF model with reappraisal ability and frequency by analysing 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 predict reappraisal, we regressed reappraisal ability and frequency on common EF factor of the nested-factor EF model. Following which, the covariates of intelligence, gender, and depressive symptomology were added to the structural models to control for the influence of crucial covariates. To inquire if reappraisal frequency moderates the relations of reappraisal ability with EF, latent moderated structural equation modelling was conducted by regressing reappraisal ability on the three EF constituents, as well as their interactions terms with reappraisal frequency, based on the three-factor and nested-factor models. To investigate if our results would differ when the EF constituents were alternatively modelled 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 as reflective of 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 2 as indications of good fit (Hu & Bentler, 1998; Tabachnick & Fidell, 2001). All reported estimates were standardised. Zero-order correlations between all variables of interest are shown in Appendix A.

Measurement models

Confirmatory factor analyses were conducted to first ascertain an adequate model fit of the EF measurement model. The three-factor and nested-factor EF (see Figure 2) 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 significantly poorer model fit than the nested-factor model, all $\Delta\chi^2 > 15.04$, ps $< .01$, and the three-factor model, all $\Delta\chi^2 > 10.40$, ps $< .01$ (see Table 2). However, the model fit of the three-factor and nested-factor models did not significantly differ from each other, $\Delta\chi^2(3) = 4.46$, $p = .22$. Accordingly, we proceeded with further analyses using the three-factor and the nested-factor EF models.

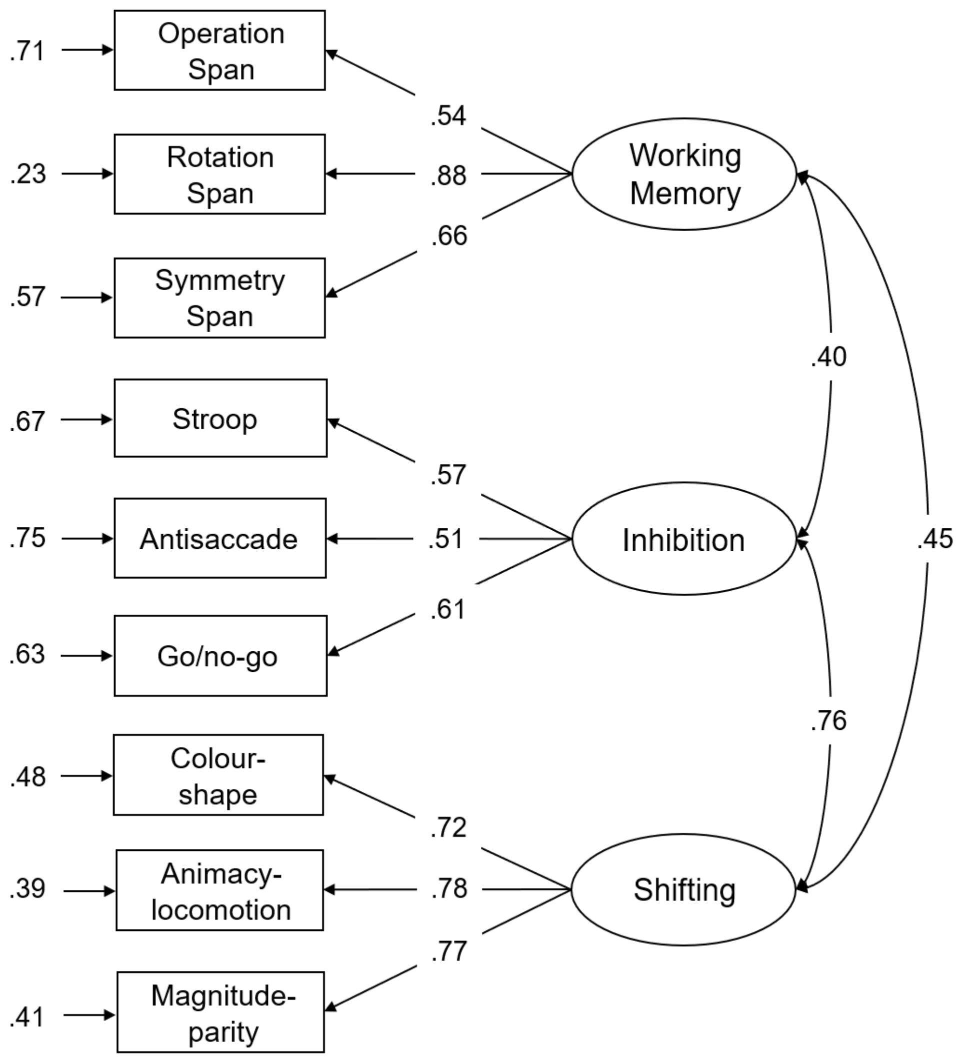

Figure 1. The three-factor EF model with standardised estimates. Ovals represent latent variables while rectangles denote manifest variables. Values for the longer, single-headed arrows signify factor loadings, while values for the shorter, single-headed arrows represent error variances. Values for the curved, double-headed arrows indicate interfactor correlations. All factor loadings, residual variances, and interfactor correlations were statistically significant at .05 level.

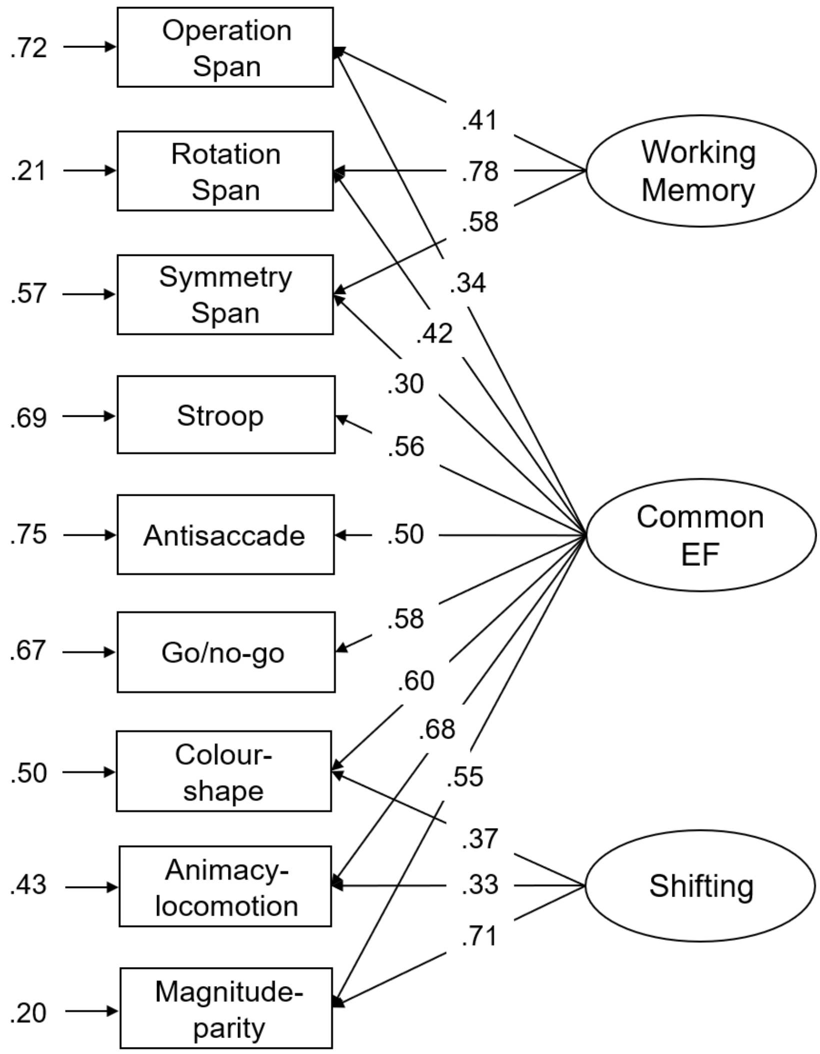

Figure 2. The nested-factor EF model with standardised estimates. Ovals represent latent variables, while rectangles denote manifest variables. Values for the longer, single-headed arrows signify factor loadings, while values for the shorter, single-headed arrows represent error variances. All factor loadings and residual variances were statistically significant at .05 level.

Table 2

Fit Indices for Measurement and Structural Models

	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	151.55	126	1.20	.035	.059	.980
Adjusted model	101.88	85	1.20	.034	.053	.986
Inhibition						
Unadjusted model	93.57	85	1.10	.024	.052	.993
Adjusted model	157.64	126	1.25	.038	.062	.974
Shifting						
Unadjusted model	88.83	85	1.05	.016	.051	.997
Adjusted model	137.95	126	1.09	.024	.057	.991
Three-factor EF models						
Unadjusted model	198.47	177	1.12	.027	.056	.986
Adjusted model with covariates	274.41	234	1.17	.032	.061	.974
Nested-factor EF models						
Unadjusted model	191.49	174	1.10	.024	.054	.988
Adjusted model with covariates	267.26	231	1.16	.030	.060	.977

Note. WM = working memory; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual; CFI = comparative fit index.

Next, the full measurement model was evaluated by adding reappraisal ability (while controlling for baseline ability) 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, $\chi^2(174) = 226.74$, χ^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 (*p*s < .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 modelling.

Structural models

To examine the associations of EF with reappraisal ability and frequency, we performed structural equation modelling 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 significantly predicted reappraisal ability ($|\gamma|$s < .36, *p*s > .05) and frequency ($|\gamma|$s < .16, *p*s > .43), and the results remained the same when covariates were added to the model ($|\gamma|$s < .30, *p*s > .11). These findings indicate that, when intercorrelations among EF latent factors were controlled for, the three EF constituents do not account for unique variance in reappraisal ability and frequency.

Subsequently, we assessed the relations of reappraisal ability and frequency with the three EF latent variables separately (see Models 1 to 3 in Table 3). The results showed that inhibition positively predicted reappraisal ability ($\gamma = .26$, $SE = .08$, $p = .003$) but not reappraisal frequency ($\gamma = .09$, $SE = .11$, $p = .371$). The relation between inhibition and reappraisal ability remained significant even when covariates were controlled for ($\gamma = .26$, $SE = .10$, $p = .011$). Shifting was significantly associated with reappraisal ability, $\gamma = .15$, *SE*

= .07, p = .043, but not frequency, γ = .13, SE = .09, p = .136; however, this relation was no longer significant when covariates were control for, γ = .15, SE = .08, p = .056. Working memory did not predict reappraisal ability and frequency, with or without covariates (|γ|s < .06, ps > .40). When the three EF components were analysed separately, the results 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-EF framework (Model 5 in Table 3). Crucially, common EF, but not working memory or shifting, was positively associated with reappraisal ability, γ = .29, SE = .08, p < .001; none of the EF constituents predicted reappraisal frequency (|γ|s < .12, ps > .24). When covariates were added to the model, the path coefficient of common EF on reappraisal ability remained significant, γ = .30, SE = .10, p = .003 (see Figure 3). Further, we obtained similar patterns of results when reappraisal ability (i.e., mean score for decrease negative trials minus mean score for look negative trials) and frequency (i.e., mean score for reappraisal frequency subscale) were modelled as manifest, instead of latent, variables. Specifically, common EF positively predicted reappraisal ability (γ = .28, SE = .08, p < .001), which remained significant even when covariates were controlled for (γ = .28, SE = .09, p = .003).

Notably, across the three-factor and nested-factor EF models, depression was the only covariate that was consistently and negatively associated with reappraisal ability and frequency (see Table 3). Contrary to the null results from the three-factor EF model, the findings for the nested-factor EF structure highlight that common EF underlies reappraisal ability, but not reappraisal frequency, even when covariates were controlled for.

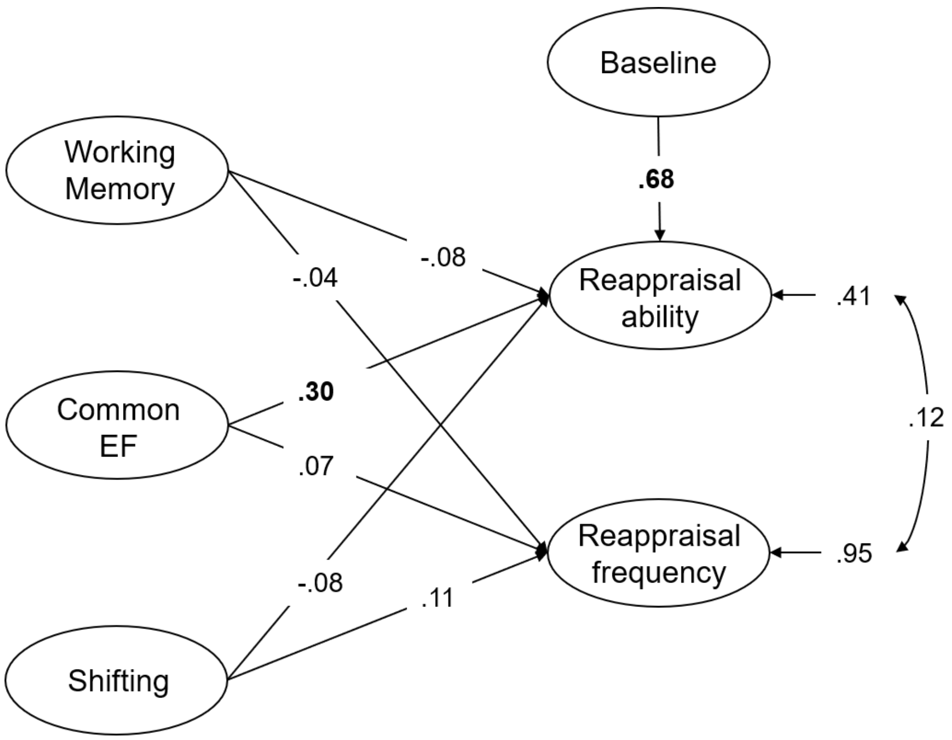

Figure 3. Structural model of working memory, common EF, and shifting predicting reappraisal ability (controlling for baseline scores) and reappraisal frequency. Covariates, factor indicators, and residual correlations among indicators are not depicted for brevity. All coefficients shown are standardised; 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.

Table 3

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

	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)**	-	**.69 (.05)**	-
Covariates				
Intelligence	-	-	.04 (.07)	.01 (.09)
Gender	-	-	**.14 (.07)**	.07 (.08)
Depressive symptomology	-	-	**-.15 (.06)**	**-.16 (.08)**
Model 2				
Focal predictor				
Inhibition	**.27 (.08)**	.09 (.11)	**.27 (.10)**	.05 (.13)
Control variable				
Baseline	**.69 (.05)**	-	**.69 (.05)**	-
Covariates				
Intelligence	-	-	-.07 (.08)	-.01 (.10)
Gender	-	-	.13 (.07)	.07 (.08)
Depressive symptomology	-	-	**-.14 (.06)**	**-.16 (.08)**
Model 3				
Focal predictor				
Shifting	**.15 (.07)**	.13 (.09)	.15 (.08)	.14 (.09)
Control variable				
Baseline	**.70 (.05)**	-	**.68 (.06)**	-
Covariates				
Intelligence	-	-	.01 (.07)	-.04 (.09)
Gender	-	-	.15 (.07)	.08 (.08)
Depressive symptomology	-	-	**-.15 (.06)**	**-.16 (.08)**
Model 4 (Three-factor EF model)				
Focal predictors				
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)
Control variable				

Baseline	**.69 (.05)**	-	**.68 (.05)**	-
Covariates				
Intelligence	-	-	-.04 (.08)	-.01 (.10)
Gender	-	-	**.14 (.07)**	.08 (.08)
Depressive symptomology	-	-	**-.14 (.06)**	**-.16 (.08)**
Model 5 (Nested-factor EF model)				
Focal predictors				
Working memory	-.08 (.08)	-.04 (.10)	-.08 (.08)	-.04 (.10)
Common EF	**.29 (.08)**	.10 (.10)	**.30 (.10)**	.07 (.12)
Shifting	-.12 (.10)	.07 (.12)	-.08 (.10)	.11 (.13)
Control variable				
Baseline	**.69 (.05)**	-	**.68 (.05)**	-
Covariates				
Intelligence	-	-	-.06 (.09)	-.02 (.10)
Gender	-	-	.13 (.07)	.08 (.08)
Depressive symptomology	-	-	**-.14 (.06)**	**-.16 (.08)**

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

Next, we conducted latent moderated structural equation analyses to examine reappraisal frequency x working memory, reappraisal frequency x common EF, and reappraisal frequency x shifting interaction terms. To this end, these interaction terms were separately added to the existing three-factor and nested-factor models. For the nested-factor model, none of the interaction terms were significant ($|\gamma|$s < .23, *p*s > .16). Likewise, null results were obtained for the interaction terms for the three-factor model when the three EF components were assessed simultaneously ($|\gamma|$s < .24, *p*s > .08) or separately ($|\gamma|$s < .12, *p*s > .34). These findings indicate that reappraisal frequency does not moderate the effects of EF constituents on reappraisal ability. Therefore, individuals with higher reappraisal frequency do not necessarily have more proficient EF to reframe negatively valenced events. Further, reappraisal frequency was not associated with reappraisal ability ($\gamma = .12$, $SE = .07$, *p*

= .071) or EF (see Figure 3), signifying 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 implemented by regressing reappraisal ability and frequency on each of the nine EF tasks (see Table 4). While several of the EF-reappraisal-ability relations reached statistical significance, there were no consistent patterns of associations between reappraisal ability and tasks that purportedly measure the same EF component. For instance, although operation span predicted reappraisal ability, the other two working memory tasks did not. Further, among the inhibition tasks, only the antisaccade and go/no-go tasks were affiliated with reappraisal ability. For the shifting tasks, the animacy-locomotion task predicted reappraisal ability, while the colour-shape task was associated with reappraisal frequency. Importantly, these findings highlight that task-specific variances in EF tasks may spuriously drive relations between EF tasks and reappraisal ability and frequency, thereby emphasising the need for the latent-variable approach to minimise the task-impurity problem.

Table 4

Standardised Regression Coefficients for Individual EF Tasks

	Unadjusted model		Adjusted model with covariates	
	Reappraisal ability	Reappraisal frequency	Reappraisal ability	Reappraisal frequency
Working memory				
Operation span	**.16 (.06)**	-.00 (.08)	**.14 (.06)**	-.03 (.08)
Rotation span	.05 (.06)	.05 (.08)	.03 (.06)	.04 (.08)
Symmetry span	-.02 (.06)	-.07 (.08)	-.04 (.06)	-.08 (.08)

Inhibition				
Antisaccade	**.18 (.06)**	-.01 (.08)	**.15 (.06)**	-.04 (.08)
Go/no-go	**.17 (.06)**	.01 (.08)	**.14 (.06)**	-.02 (.08)
Stroop	.07 (.06)	.11 (.08)	.06 (.06)	.11 (.08)
Shifting				
Colour-shape	**.12 (.06)**	**.16 (.08)**	.11 (.06)	**.17 (.08)**
Animacy-locomotion	**.15 (.06)**	.06 (.08)	**.13 (.06)**	.05 (.08)
Magnitude-parity	.06 (.06)	.06 (.08)	.06 (.06)	.07 (.08)

Note. Values denote standardised regression coefficients with standard errors in parentheses. Significant values are marked in boldface, $p < .05$.

Discussion

Our study yielded several notable outcomes. First, we found that the shared, rather than unique, variance among EF processes (i.e., common EF) positively predicted reappraisal ability. Results from the three-factor EF model showed that when all three EF constituents were assessed simultaneously and their shared variance was partialled out, none of the EF constituents were uniquely related to reappraisal ability. However, when EF was conceptualised as nested-factor model, which reflects the revised unity/diversity EF framework (Miyake & Friedman, 2012), the common EF component significantly predicted reappraisal ability. Further, the link between common EF and reappraisal held true even when covariates were controlled for, thereby ruling out alternative explanations that our finding was driven by third variables such as intelligence, gender, and depressive symptomology. Pivotally, our results allude that the previously reported associations of working memory, inhibition, and shifting with reappraisal ability (Malooly et al., 2013; McRae et al., 2012; Pe, Raes, Koval, et al., 2013; Schmeichel & Tang, 2014) may be driven by a common EF component instead. Specifically, common EF may aid in the activation, maintenance, and selection of positive (or neutral) situational narratives, resisting interference from competing negative appraisals, and monitoring how successful one is in achieving the goal of regulating affective state. Our results converge with recent findings based on the nested-factor EF model which positions common EF as the most vital correlate of various behavioural outcomes. For instance, common EF negatively predicted substance abuse (Gustavson et al., 2017), procrastination (Gustavson et al., 2015), implicit racial biases (Ito et al., 2015), and trait worry (Gustavson et al., 2019). However, these behavioural outcomes were either nonsignificantly or weakly related to other EF components (i.e., working memory and shifting). 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 conceptualised at the latent-variable level relative to the individual-task level. To illustrate, certain aspects of our multiple regression results are consistent with past studies that have relied on single-task measures of EF. For instance, the operation span task was found to positively predict reappraisal ability, which dovetails past findings showing that higher levels of reappraisal ability were concomitant with better performance on the operation span task (McRae et al., 2012; Schmeichel et al., 2008). Further, the positive association between the go/no-go task and reappraisal ability is in line with the results from past studies that have used the stop-signal task (Tabibnia et al., 2011), which similarly requires one to withhold from responding to a specific target. Moreover, the finding that the animacy-locomotion task was positively related with reappraisal ability is partially congruent with past findings that have documented the associations of reappraisal ability with neutral and affective variants of the task-switching paradigm (Malooly et al., 2013; McRae et al., 2012). However, we found that other measures that purportedly assess the same EF components of working memory (i.e., rotation and symmetry span), inhibition (i.e., Stroop task), and shifting (i.e., colour-shape and magnitude-parity tasks) did not consistently yield the same pattern of findings. Such discrepancies point to task-impurity problems among EF tasks. Specifically, positive relations between EF and reappraisal ability from past studies can be potentially attributed to either common EF inherent in the given EF task or task-specific processes that are unrelated to EF (e.g., processing speed, colour discrimination, etc.). Consequently, the reliance on individual EF tasks may lead to specious and potentially misleading relations that do not generalise to other construct-similar EF tasks, thereby underscoring the utility of the latent-variable approach in examining EF.

Third, contrary to the results for reappraisal ability, we did not find a meaningful association between EF and reappraisal frequency. This finding is consistent with past studies which tend to report direct relations between working memory and performance-based, but not self-reported, measures of reappraisal (McRae et al., 2012; Pe, Raes, Koval, et al., 2013). Further, we found that 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, reappraisal ability reflects how competent one is in downregulating negative affect; correspondingly, EF would be more closely affiliated with reappraisal ability, which is congruent with extant neuroimaging studies highlighting that similar brain regions subserve EF and reappraisal ability (e.g., Goldin et al., 2008; Ochsner et al., 2004). In contrast, reappraisal frequency represents 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)—which may be unrelated to EF. Further, our null findings also suggest that more frequent use of reappraisal does not necessarily translate to higher levels of EF or reappraisal ability. However, given that the negatively valenced stimuli used in our reappraisal task may or may not reflect negative experiences that individuals face in daily functioning, it remains to be seen if different results would be obtained if reappraisal ability was assessed using more ecologically valid stimuli. Moreover, given that self-reported measures of reappraisal frequency may be susceptible to reporting biases (Schwarz & Strack, 1999), more work is needed to ascertain our findings using experience sampling methods, which would afford more reliable and accurate estimates of reappraisal frequency.

Our study is not without limitations. First, the correlational nature of our research restricts causal inferences. For instance, while our results show that common EF predicts reappraisal ability, it is plausible that more proficient reappraisal ability engenders better EF instead, given that EF has been shown to be malleable to experiential inputs (Diamond, 2013). Therefore, longitudinal designs are needed to ascertain the directionality of the relations between EF and reappraisal. Second, although we have established common EF as a crucial cognitive correlate of reappraisal, there may be other cognitive factors that are involved in reappraisal. For instance, the generation of alternative narratives may require task-relevant information retrieval from long-term memory. Indeed, there is some evidence that tasks requiring memory retrieval (e.g., verbal fluency tasks) predict difficulties in reappraisal among brain-damaged patients (Salas et al., 2014). Accordingly, uncovering other cognitive mechanisms that underpin reappraisal processes would be an important future direction. Third, as 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, past work has identified the potential role of EF in ruminative tendencies (Altamirano, Miyake, & Whitmer, 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 if such associations would hold at the latent-variable level. Fourth, since our sample comprised young undergraduate adults, our obtained findings may not be generalisable 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 adult and adolescent/child samples, respectively (Karr et al., 2018). Further, 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). To this end, future work should extend our findings with other age groups, such as adolescents and older adults.

To reiterate, the key strengths of our study include the comprehensive assessment of various EF facets and reappraisal processes (i.e., ability and frequency), as well as the use of the latent-variable approach to deal with the task-impurity problem among EF tasks. Theoretically, our findings highlight 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 underpins the ability to reappraise negative experiences. Methodologically, our results demonstrate that disparate conclusions may be attained when EF is assessed at the individual-level, thereby reinforcing the need to measure EF using multiple tasks at the latent-variable level. In essence, our findings provide crucial theoretical, methodological and empirical advancements toward a better understanding of how EF facilitates reappraisal.

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Appendix A

Table A

Zero-order Correlations between Variables of Interest

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1. Antisaccade	-																						
2. Go/no-go	**.20**	-																					
3. Stroop	**.30**	.13	-																				
4. Operation	**.29**	.07	.12	-																			
5. Rotation	**.30**	.07	**.20**	**.45**	-																		
6. Symmetry	.14	.06	.11	**.32**	**.58**	-																	
7. CS	**.29**	**.16**	**.36**	**.22**	**.22**	**.25**	-																
8. AL	**.24**	**.19**	**.39**	**.23**	**.36**	**.22**	**.53**	-															
9. MP	**.24**	.09	**.25**	**.19**	**.30**	**.19**	**.59**	**.60**	-														
10. RF item 1	-.11	.02	.04	.00	.03	-.05	.13	.05	.00	-													
11. RF item 2	-.01	.04	.08	.03	.05	-.14	.11	.03	.06	**.58**	-												
12. RF item 3	.00	.02	.10	.01	.06	.02	.04	.05	.00	.14	**.28**	-											
13. RF item 4	-.03	.03	.06	-.03	-.03	-.07	.14	.05	.05	**.51**	**.53**	**.43**	-										
14. RF item 5	-.02	.07	-.04	.08	.14	.09	.03	-.06	-.01	.12	.07	.07	.06	-									
15. RF item 6	.04	.05	.07	.01	.05	-.04	**.16**	.05	.09	**.40**	**.55**	**.49**	**.77**	.08	-								
16. RA-DN P1	.14	.01	**.18**	**.16**	.12	.05	.14	**.20**	.10	-.07	-.01	.10	.04	-.12	.05	-							
17. RA-DN P2	**.18**	.02	**.17**	**.16**	.10	.06	.12	**.21**	.12	.00	.12	**.18**	.08	-.06	**.17**	**.71**	-						
18. RA-DN P3	**.20**	-.04	.07	.12	.11	-.01	.13	**.16**	.05	-.04	.06	.13	.08	-.05	.09	**.61**	**.72**	-					
19. RA-LN P1	-.01	-.10	.13	-.03	.06	.01	-.02	.04	.02	-.03	.01	.10	.01	.13	.05	**.51**	**.49**	**.38**	-				
20. RA-LN P2	.08	-.07	**.18**	.09	**.16**	.14	.13	**.15**	.12	-.11	-.02	.06	-.02	-.04	.07	**.55**	**.52**	**.41**	**.66**	-			
21. RA-LN P3	.02	-.09	.07	-.07	.11	.07	.02	.11	.03	**-.18**	-.07	.08	-.05	-.02	.01	**.48**	**.54**	**.42**	**.67**	**.68**	-		
22. RSPM-SF	**.38**	.06	**.19**	**.33**	**.32**	**.26**	**.24**	**.31**	**.27**	.01	-.04	.10	-.02	.09	.02	.13	.11	.05	-.05	.11	.10	-	
23. CES-D-10	-.07	-.03	-.04	-.06	-.02	-.00	-.09	-.04	.01	-.08	-.10	-.09	-.12	**.16**	-.14	**-.21**	-.11	-.10	-.03	-.03	.00	-.06	-
24. Gender	**.17**	-.02	-.00	.09	.09	.08	-.06	.06	-.03	.11	.09	.11	.07	**.22**	.04	**.24**	**.21**	**.19**	**.25**	.14	.10	.12	.05

Note. Significant correlations marked in boldface, $p < .05$. CS = colour-shape; AL = animacy-locomotion; MP = magnitude-parity; RF = reappraisal frequency; RA = reappraisal ability; DN = “Decrease Negative” trials; LN = “Look Negative” trials; P1 – P3 = parcels 1 to 3; RSPM-SF = Raven’s Standard Progressive Matrices Short-Form; CES-D-10 = Centre for Epidemiological Studies-Depression 10-item short form. Gender was coded as 0 = *female*, 1 = *male*.