To Switch or Not to Switch? Individual Differences in Executive Function and Emotion Regulation Flexibility

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Abstract

Emotion regulation (ER) constitutes strategies that modulate the experience and expression of emotions. While past work has predominantly assumed that ER strategies are consistently adaptive (or maladaptive) across situations, recent research has begun to examine individual-difference factors that are associated with the flexible use of ER strategies in line with contextual demands (i.e., ER flexibility). Theoretical accounts maintain that the choice to use ER strategies in a given context is contingent on individual differences in executive function (EF), which refers to a collection of general-purpose regulatory operations. Based on a comprehensive battery of EF tasks, we investigated how the various EF facets (i.e., common EF, working-memory-specific, and shifting-specific factors) are related to the frequency of maintaining and switching ER strategies in response to stimuli that elicit varying levels of emotional intensity. Results indicated that individuals with higher EF demonstrated a more flexible pattern of ER strategy use across high- and low-intensity conditions. Specifically, better working-memory-specific ability (i.e., manipulating information within a mental workspace) was associated with a greater frequency of reappraisal-to-distraction strategy switching in high-intensity contexts. Furthermore, more proficient common EF (i.e., sustaining relevant goals in the face of competing goals and responses) corresponded to a higher propensity to maintain the use of reappraisal in low-intensity situations. The outcomes of this study offer a first glimpse of the cognitive factors underlying ER flexibility.

Keywords: executive function, reappraisal, distraction, emotion regulation flexibility, emotion regulation choice

To Switch or Not to Switch? Individual Differences in Executive Function and Emotion Regulation Flexibility

Emotion regulation (ER) refers to processes that modify how and when emotions are expressed and experienced (Gross, 2008). Two widely studied ER strategies are cognitive reappraisal (henceforth *reappraisal*), which relates to the reframing of one or more interpretations of a situation to increase or decrease its emotional impact, and distraction, which refers to diverting attention away from emotional aspects of a situation, or away from the situation altogether, toward unrelated neutral thoughts or information (Gross, 2008). Decades of research have documented the roles of reappraisal and distraction in various domains in life, such as interpersonal relations, self-esteem, resilience, and subjective well-being (Gross & John, 2003; Sheppes & Gross, 2011; Webb et al., 2012). However, there is increasing recognition that ER strategies are not used uniformly across every situation, thereby highlighting the importance of selecting ER strategies that are synchronized with contextual demands (i.e., ER flexibility; Aldao et al., 2015; Ford & Troy, 2019). Whereas past research has demonstrated that the ability to successfully regulate emotional experiences is dependent on a collection of general-purpose control processes—known as executive function (EF; Schmeichel & Tang, 2014, 2015)—less is known regarding the role of EF in the flexible use of ER strategies. Given that EF has been theorized to be involved in ER flexibility (Pruessner et al., 2020; Sheppes et al., 2014), we sought to investigate how the various EF dimensions (i.e., common EF, working memory-specific, and shifting-specific factors) would be associated with a pivotal component of ER flexibility: the choice to maintain or switch ER strategies.

Reappraisal and Distraction

While reappraisal and distraction are recognized as antecedent-focused ER strategies (i.e., tactics targeting emotional responses that are not fully developed), they differ in their cost-benefit profiles. As a disengagement strategy, distraction modulates the emotion-generative trajectory at an early stage by preventing the elaborated evaluation or processing of affective information (Sheppes & Gross, 2011). As an engagement strategy, reappraisal modifies emotion generation at a relatively later stage, whereby emotional information passes the early attentional stage and is in the process of being afforded elaborated meaning (Sheppes & Gross, 2011). In downregulating negative affect, distraction has been shown to be effective for both low-intensity and high-intensity situations, while the benefits of reappraisal are isolated to low-, but not high-, intensity contexts (Sheppes & Meiran, 2007, 2008). Accordingly, distraction provides short-term relief by quickly and effectively regulating undesired emotions, especially under time constraints or high-intensity situations, while reappraisal offers long-term adaptation by helping to make sense of emotional events such that future occurrence of the same events can be dealt with more successfully (McRae, 2016).

Whereas prior research has predominantly assumed that ER strategies, such as distraction and reappraisal, are consistently adaptive (or maladaptive) across situations (Bonanno & Burton, 2013), recent work has begun to examine the role of contextual factors in the use of ER strategies. For instance, when facing highly intense emotional situations, it may be too cognitively taxing to employ reappraisal, which requires engaging with—and transforming the meaning of—emotion-eliciting stimuli. Specifically, in a study by Sheppes et al. (2011) that used a variety of emotion-eliciting pictures, participants preferred reappraisal for low-intensity negative pictures, while distraction—a cognitive disengagement strategy—was preferred for

high-intensity negative pictures. Using the same emotion-regulation choice paradigm, Levy-Gigi et al. (2016) found that traumatic exposure was positively correlated with posttraumatic stress disorder symptoms among firefighters who more frequently selected reappraisal, instead of distraction, for high-intensity negative pictures, thereby suggesting that lower regulatory-choice flexibility may be a risk factor for psychopathology. Another study by Birk and Bonanno (2016) showed that individuals with greater responsiveness to internal feedback (i.e., corrugator activity, heart rate) predicted the tendency to switch from a suboptimal (i.e., reappraisal) to an optimal (i.e., distraction) strategy in response to high-intensity negative pictures. Moreover, for individuals with higher levels of responsiveness to internal feedback, more frequent reappraisal-to-distraction switches were concomitant with higher life satisfaction. Together, the findings from past studies show that the use of reappraisal and distraction are contingent on contextual and individual-difference factors.

Executive Function and Emotion Regulation Flexibility

A popular conceptualization of EF is the unity/diversity framework (Miyake et al., 2000), which details three intercorrelated (i.e., unity) but separable (i.e., diversity) regulatory processes—inhibition, working-memory updating, and shifting—as derived from a confirmatory factor analysis of a battery of nine commonly used EF tasks. Inhibition refers to the suppression of prepotent or automatic response tendencies. Working-memory updating (henceforth working memory) relates to the manipulation and updating of information within a mental workspace. Shifting concerns the flexible back-and-forth switching between multiple mental sets and tasks. In a recent revision of the unity/diversity framework (Friedman & Miyake, 2017), a common EF factor—which involves the ability to activate and maintain task-relevant information and goals—has been proposed to represent the intercorrelations between all three EF facets. In this model,

after the common EF factor (i.e., unity) has been extracted, working-memory-specific and shifting-specific factors (i.e., diversity) were formed from the remaining variance unique to working-memory and shifting processes, respectively, with no more unique variance among inhibition tasks to establish an inhibition-specific factor. Notably, a growing body of evidence supports the idea that EF comprises a general, shared component (i.e., common EF) as well as unique, distinct components (i.e., working-memory- and shifting-specific factors; for a review, see Friedman & Miyake, 2017).

Current theories in affective science highlight the idea that ER success relies on cognitive resources—most prominently, EF (Schmeichel & Tang, 2015; Toh & Yang, 2022). For instance, the ability to reappraise emotional experiences requires the manipulation of narratives in one's mind (working memory), suppression of undesired appraisals in favor of desired interpretations (inhibition), and switching from goal-incongruent to goal congruent narratives through the reconfiguration of interpretations while resisting proactive interference from initial appraisals (shifting). Findings from past studies have substantiated the link between EF and reappraisal. For instance, performance on working-memory measures (e.g., operation-span and keep-track tasks) was positively associated with the ability to reappraise affective stimuli (Hendricks & Buchanan, 2016; McRae et al., 2012). Furthermore, individuals with frontal-lobe impairments exhibited greater difficulties on both inhibition and reappraisal tasks compared with healthy controls (Salas et al., 2014; Tabibnia et al., 2011). Moreover, proficient shifting between different task sets corresponded with the ability to adopt a detached, objective perspective when viewing evocative film clips and pictures (Liang et al., 2017; Malooly et al., 2013). Recent findings, however, clarify that reappraisal ability is primarily driven by the common EF ability to sustain ER goals

and relevant information rather than processes unique to working memory and shifting (i.e., working-memory-specific and shifting-specific factors; Toh & Yang, 2022).

Less is known, however, about the interplay between EF and ER flexibility, which relates to the flexible use and implementation of situationally appropriate ER strategies in accord with changing contextual demands and personal goals (Bonanno & Burton, 2013). Extant theoretical accounts on ER flexibility (e.g., Bonanno & Burton, 2013; Gross, 2015) specify several key regulatory processes: (a) perceiving situational demands and identifying whether ER is required, (b) selecting from a repertoire of available strategies, (c) implementing the selected strategy by translating the general strategy into specific tactics that are appropriate to the situation, and (d) monitoring and evaluating the effectiveness of a chosen strategy to adjust and correct behavior as needed, which includes maintaining the ongoing regulatory approach or switching from one strategy to another.

Past work, though limited, on EF and ER flexibility has focused on the strategy selection (or repertoire) stage, which can be indexed by the type and variability of ER strategies employed across situations (Bonanno & Burton, 2013). Among younger adults, Eldesouky and English (2018) found that higher overall performance on EF tasks (i.e., verbal fluency, Stroop, and Attention Network tasks) predicted lower variability in the self-reported daily use of various ER strategies (i.e., situation selection, situation modification, distraction, positive reappraisal, detached reappraisal, and expressive suppression). In a study by Scheibe et al. (2015), younger (19–28 years) and older (65–75 years) adults completed an inhibition measure (i.e., flanker task) as well as a laboratory-based ER-choice task in which they were shown emotion-eliciting pictures with differing intensity levels and had to select reappraisal or distraction. Results indicated that older adults preferred distraction over reappraisal across both low- and high-

intensity pictures and that both younger and older adults with less proficient inhibition more frequently opted for distraction over reappraisal, thereby suggesting that individuals with diminished cognitive resources compensate by choosing ER strategies (other than reappraisal) that are less cognitively demanding (e.g., distraction; Urry & Gross, 2010). Together, the evidence indicates that lower EF is linked to higher variability in ER strategy use and a greater likelihood of selecting strategies that are less cognitively demanding.

Limitations of Prior Research

Limited evidence on the link between EF and ER flexibility and their shortcomings hinder definitive conclusions. The first major issue concerns methodological limitations. Specifically, prior research has employed independent and inadequate assessments of EF dimensions and relied on a single EF task to represent the EF facet of interest. This approach has two notable drawbacks. Foremost, given that EF tasks typically assess construct-relevant and construct-irrelevant processes (known as the task-impurity problem), the use of single EF measures (e.g., flanker task; Scheibe et al., 2015) makes it difficult to ascertain whether EF or non-EF abilities are involved in ER flexibility. Indeed, past work has shown that findings from a single EF measure do not generalize to related tasks that are supposed to tap the same EF dimension (Gustavson et al., 2020; Toh & Yang, 2022). Second, given that each EF facet comprises shared (i.e., common EF) and unique (i.e., working-memory-specific and shifting-specific) components (Friedman & Miyake, 2017), focusing on only one or two EF facets (e.g., working memory and inhibition; Eldesouky & English, 2018; Scheibe et al., 2015) hinders a thorough understanding of the contribution of EF to ER flexibility. Furthermore, the different EF components are not similarly predictive of—and sometimes show opposing relations with—behavioral outcomes (e.g., Friedman et al., 2011; Toh et al., 2023). Accordingly, a

comprehensive examination of EF, along with appropriate statistical techniques, is warranted to more precisely approximate EF components and elucidate how they are implicated in ER flexibility.

Another major issue in the literature relates to the lack of evidence on how EF facets are recruited in the decision to maintain ongoing regulatory efforts or to switch from one strategy to another (Bonanno & Burton, 2013). Notably, the cognitive-control framework of ER flexibility posits that maintaining an existing ER strategy versus switching ER strategies involves the decision to engage in stability and flexibility modes of control (Dreisbach & Fröber, 2019) that are reliant on the EF abilities of inhibition, working memory, and shifting (Pruessner et al., 2020). Strategy maintenance encompasses the conversion of regulatory goals into context-specific tactics without being disrupted by internal or external task-irrelevant distractions, thereby ensuring that one's emotions remain regulated until the desired emotional state has been achieved. In this regard, strategy maintenance implicates the stability mode of control, which includes sustaining relevant strategy-specific information while preventing distractors from interfering with ongoing regulatory processes (inhibition) as well as retaining relevant regulatory information within a mental workspace (working memory; Pruessner et al., 2020). Conversely, strategy switching, which is the capacity to discontinue a present ER strategy and switch to a more appropriate strategy, entails the flexibility mode of control (Pruessner et al., 2020). Specifically, strategy switching involves stopping current ER processes and switching to a different ER strategy or other goals (shifting); suppressing or resolving the impulse to continue with a previous ER strategy (inhibition); and updating or replacing outdated material with more relevant information regarding ER processes (working memory).

However, given that EF comprises common and unique processes that are differentially predictive of ER and affective experiences (e.g., Gustavson et al., 2020; Toh & Yang, 2022), it is crucial to examine how common EF as well as working-memory-specific and shifting-specific abilities are linked to ER flexibility. For instance, the stability mode of control during strategy maintenance has been theorized to implicate inhibition and working-memory processes that shield ER strategies from distractions by attentionally focusing on, and maintaining, present ER demands and goals (Pruessner et al., 2020). However, these processes could be underpinned by common EF that is potentially integral in activating and sustaining pertinent ER goals and strategies. Notably, the stability mode of control principally involves the common EF ability to manage goal-relevant information (Dreisbach & Fröber, 2019), which is a core mechanism of inhibition and working-memory processes (Engle & Kane, 2004; Friedman & Miyake, 2017). Therefore, common EF is a plausible correlate of strategy maintenance.

Conversely, strategy switching pertains to the flexibility mode of control (Pruessner et al., 2020), which is characterized by the ability to switch and adapt actions and thoughts to task demands, that entails keeping multiple tasks active (common EF) and adjusting the updating threshold to facilitate the access of information within a mental workspace (working-memory-specific ability; Dreisbach & Fröber, 2019). Likewise, changing regulatory approaches may uniquely involve switching from an existing strategy to a more appropriate one (shifting-specific ability). Correspondingly, the different EF components (i.e., common EF, working-memory-specific, and shifting-specific abilities) could be concomitant with effectively maintaining, gating, and switching between ER-related information and goals in one's mind.

The Present Study

Motivated by the issues highlighted, the goals of the current study are as follows. First, in order to tackle the task-impurity problem in EF measures, we employed a latent-variable approach based on multiple tasks to measure each EF dimension. Notably, the latent-variable approach provides a cleaner estimation of EF facets by accounting for measurement error and task-specific, non-EF processes (Friedman & Miyake, 2017; Miyake et al., 2000), thereby affording greater precision in examining the relations between EF and ER flexibility. Furthermore, based on the unity and diversity of EF (Friedman et al., 2008), we estimated the following EF models: (a) the three-factor model (i.e., inhibition, working memory, and shifting), which forms the conceptual basis for the cognitive-control framework of ER flexibility (Pruessner et al., 2020); and (b) the second-order factor model, which provides greater theoretical clarity in how the shared (i.e., common EF) and unique EF components (i.e., working-memory-specific and shifting-specific factors) are associated with ER flexibility.

Second, to empirically test the links between EF and ER strategy maintenance and switching, we adopted the experimental paradigm by Birk and Bonanno (2016), which focuses on individual differences in the tendency, or preference, to maintain or switch strategies. Specifically, participants were instructed to first reappraise emotion-eliciting pictures, which varied in intensity levels, and then choose to continue using reappraisal or switch to distraction, thereby allowing us to examine how strategy maintenance and switching would be related to EF across different emotional contexts. Considering that past research has shown that reappraisal and distraction are preferred in low- and high-intensity situations, respectively (e.g., Scheibe et al., 2015; Sheppes et al., 2011), we anticipated higher frequency of strategy switching (i.e., from reappraisal to distraction) for high-intensity contexts and lower frequency of strategy switching (i.e., maintaining reappraisal) for low-intensity contexts. Specifically, reappraisal is favored in

low-intensity situations owing to the attenuation of emotional experiences and the facilitation of affective adaptation. In contrast, distraction is preferred in high-intensity situations because it hinders affective information at an early stage before it gains momentum (Sheppes et al., 2014).

Applying the postulates of the cognitive-control framework of ER flexibility (Pruessner et al., 2020) to how low- and high-intensity affective contexts affect strategy choice, the following hypotheses were tested. In low intensity environments that favor strategy maintenance of reappraisal, better inhibition and working-memory abilities would be concomitant with higher strategy-maintenance frequency. In high-intensity environments that are conducive to reappraisal-to-distraction strategy switching, more proficient inhibition, working-memory, and shifting abilities would be associated with greater strategy-switching frequency. Based on the second-order factor model (Friedman et al., 2008), we further hypothesized that higher common EF would be related to greater strategy-maintenance frequency in low-intensity contexts, while better common EF, working-memory-specific, and shifting-specific abilities would be linked to more frequent strategy switching in high-intensity contexts. Additionally, to ensure that the associations between EF and ER flexibility are not attributed to third-variable effects, we controlled for potential covariates (i.e., gender, depressive symptoms, reappraisal ability, and distraction ability) that have been documented to influence EF and ER flexibility (Birk & Bonanno, 2016; Cornblath et al., 2019; Goubet & Chrysikou, 2019; Snyder, 2013; Toh & Yang, 2022; Westphal et al., 2010).

Method

Participants

Two hundred and twelve undergraduate students (M_{age} = 22.22 years, SD_{age} = 1.81 years) participated in the two-session study for course credits or a monetary reward (S$50). Our sample size was determined by the following criteria. First, Monte Carlo simulations (1,000 iterations) revealed that a structural equation model with four latent variables and 11 manifest variables (see "Results") requires n = 162 to detect a medium effect size of .30, as observed in previous studies that used structural equation modeling to investigate EF and ER processes (e.g., Toh & Yang, 2022). Second, findings from Schönbrodt and Perugini's (2013) simulation study indicate that medium effect sizes of *r*s = .30–.40, with a corridor of stability of ±0.10, tend to stabilize at around n = 181–212. Four participants did not successfully complete both sessions of the study, and therefore, data from 208 participants were eventually used for analyses. Descriptive statistics for all variables of interest and zero-order correlations are shown in Table 1.

Table 1

Descriptive Statistics and Zero-Order Correlations Between Variables of Interest

	M	*SD*	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Predictors[a]																		
1. Keep track	0.79	0.08	0.49	0.96	-													
2. Two-back	0.94	0.04	0.77	1.00	**.33**	-												
3. Corsi	62.57	21.94	0.00	112.00	**.21**	**.33**	-											
4. Antisaccade	0.63	0.20	0.25	0.99	**.25**	**.30**	**.20**	-										
5. Go/no-go	0.44	0.18	0.00	0.88	**.15**	.11	.09	**.30**	-									
6. Stroop	0.90	0.08	0.54	1.00	**.25**	**.21**	**.18**	**.22**	**.24**	-								
7. Magnitude parity[b]	13.14	2.12	6.48	17.37	.13	**.20**	.13	**.27**	**.34**	**.24**	-							
8. Animacy locomotion[b]	13.51	2.61	2.87	18.00	.09	.12	.14	**.28**	**.25**	**.23**	**.43**	-						
9. Color shape[b]	13.66	2.07	5.15	18.17	.11	**.16**	**.26**	**.31**	**.29**	**.30**	**.49**	**.31**	-					
Criterion[c]																		
10. Low-intensity maintenance frequency	0.88	0.19	0.00	1.00	.06	.06	-.07	**.25**	**.19**	.09	**.23**	**.17**	**.38**	-				
11. High-intensity switching frequency	0.48	0.21	0.00	1.00	.10	.13	.12	-.05	-.14	-.09	**-.16**	-.05	**-.24**	**-.49**	-			
Covariates																		
12. Reappraisal ability[d]	0.00	0.81	-2.17	2.35	.13	-.02	.06	.12	.09	.10	.04	.01	-.02	.05	-.07	-		
13. Distraction ability[d]	0.00	1.18	-3.49	2.21	**.17**	.06	.07	.08	.11	.06	**.16**	.08	.13	**.18**	-.04	**.19**	-	
14. Gender (% female)[e]	70.67	-	-	-	-.01	.01	.04	.03	.07	.10	.06	.04	.12	.05	-.14	.10	.05	-
15. Depressive symptoms	2.11	0.59	1.10	3.80	**-.14**	-.02	.01	-.04	-.14	-.02	-.12	-.05	-.13	-.01	.02	.05	**-.14**	**-.18**

Note. SD = standard deviation; EF = executive function. Statistically significant correlations are marked in boldface, $p < .05$.

[a] Due to technical problems, data were missing for the following EF tasks: keep track (n = 2), two-back (n = 7), go/no-go (n = 1), Stroop (n = 9), and animacy-locomotion (n = 1). Also, a procedural error resulted in the Corsi block-tapping task not being administered to 19% of the participants (n = 40).
[b] For the magnitude-parity, animacy-locomotion, and color-shape tasks, bin scores were reverse coded such that higher values indicated better performance.
[c] Higher values for the low-intensity and high-intensity conditions reflect greater proportion of strategy maintenance and strategy switching, respectively. Following Birk and Bonanno (2016), participants who did not switch at all or switched all the time were excluded (n = 30).
[d] Reappraisal and distraction abilities were indexed by residualized scores, as computed by regressing mean ratings for the “Reframe” (reappraisal) or “Distract” (distraction) condition on mean ratings for negative images on the “Look” condition. Residualized scores were reverse coded such that higher values represented higher reappraisal and distraction success.
[e] Gender was coded as 0 = *female*, 1 = *male*.

Materials

Inhibition

Antisaccade. Adapted from Unsworth and McMillan (2014), participants had to ignore a flashing distractor on one side of the screen in order to detect a target (i.e., *B*, *P*, or *R*) that was briefly shown on the other side of the screen. Each trial began with the presentation of a fixation point in the center of the screen for a variable period of time (200–2,200 ms). Next, the distractor (100 ms), in the form of an equal sign, was flashed either to the left or right of the fixation point (11.33° of visual angle). This was followed by a blank screen (50 ms) and the second appearance of the distractor (100 ms) to intensify the attentional capture of the distractor. After another presentation of a blank screen (50 ms), the target (150 ms) appeared on the opposite side from where the previously shown distractor had appeared (11.33° relative to the fixation point). Finally, the target was masked by the letter *H* (50 ms) and the number *8* until a response was provided. There were 24 practice trials and 72 experimental trials. A higher proportion of correct responses denoted better performance.

Go/No-Go. Adapted from McVay and Kane (2009), participants responded to non-*X* letters (i.e., go trials) by pressing the spacebar on the keyboard, except for the target *X* letter (i.e., no-go trials). In each trial, a letter stimulus was first shown (400 ms), followed by a blank screen (900 ms) or until a response was given. There were 267 go trials and 33 no-go trials. The infrequent presentation of the *X* letter (11% of the time) implicates inhibition of the impulse to press the spacebar. A higher proportion of correct responses on the no-go trials denoted more proficient performance.

Stroop. In this variant of the Stroop task (Altamirano et al., 2010), participants discerned the color of a target word—rather than reading the word (e.g., the word "red" printed in blue ink)—by pressing the *R* (red), *Y* (yellow), *G* (green), or *B* (blue) key. Each trial began with a fixation point (750 ms) followed by the target word, which remained on the screen for 2,000 ms or until a response was provided. There were two types of trials: (a) 144 congruent trials in which the target word matched the color it was printed in (e.g., the word "blue" printed in blue ink) and (b) 48 incongruent trials in which the target word conflicted with the color in which it was printed in (e.g., the word "green" printed in yellow ink). Participants completed 10 practice trials before completing 192 experimental trials that were randomly presented. Following Altamirano et al. (2010), a higher proportion of correct responses on the incongruent trials indicated better performance.

Working Memory

Keep Track. Adapted from Yntema (1963), participants were presented with words that belonged to different categories (i.e., animals, distances, relatives, colors, and countries) and had to recall the last item from each category. In each trial, 15 items were shown one at a time in the middle of the screen for 1,500 ms each, and the target categories were displayed at the bottom of the screen. There were 12 trials, and the maximum number of to-be-recalled items in each trial (set size) randomly ranged from 2 to 4. A higher proportion of correctly recalled items signified better performance.

Two Back. In this version of the *n*-back task (Jaeggi et al., 2010), participants viewed a sequentially presented string of numbers and had to indicate, by pressing the spacebar, whether the current number matched the number shown two trials before. In each trial, the to-be-remembered number was shown for 1,500 ms, and the interval between each number was 1,000

ms. There were four blocks with 17 letters each. A higher proportion of accurate responses represented better performance.

Corsi Block Tapping. A computerized backward span version of the Corsi block-tapping task was implemented (Kessels et al., 2008). In each trial, an array of nine cubes, which lit up one at a time (1,000 ms) in a random order, was presented. Participants had to tap on the cubes in the reverse order in which they lit up. There were two trials per set size, which ranged from 2 to 8, and the task was terminated once both trials of a set size were incorrect. Following Kessels et al. (2008), a product score was computed by multiplying the highest set size achieved with the total number of correct responses; higher values denoted better performance.

Shifting

Color Shape. Depending on a given cue, participants sorted a target (i.e., red triangle or green circle) according to either the color (i.e., red or green) or shape rule (i.e., triangle or circle) by pressing the *D* (i.e., circle or red) or *K* (i.e., green or triangle) keys. The cues for the color and shape rules were a color gradient and a row of black squares, respectively. In each trial, a fixation point (350 ms) and then a blank screen (150 ms) were shown. Next, the cue was presented, followed by the target after a delay (250 ms). Both the cue and the target remained on the screen until a response was provided. The interval between the response and the next trial was 800 ms, as signified by a blank screen. Two pure blocks comprised only color or shape rules (20 trials each), followed by two mixed blocks (30 trials each) with an equal number of switch (e.g., color rule followed by shape rule) and repeat trials (e.g., two consecutive trials of color rule). The trial order was randomized, with the maximum number of consecutive repeat trials set at four. The dependent variable was reverse-coded bin scores (see Binning Procedure), in which higher values denoted better performance.

Magnitude Parity. Based on the cue presented, participants sorted a target (2 or 7) according to the magnitude (smaller or greater than five) or parity rule (odd or even) by pressing the *D* (odd number or less than five) or *K* (even number or more than five) key. Cues for the magnitude and parity rules were signified by rows of circles of varying sizes and rows of odd- and even-numbered squares, respectively. All other methodological details were similar to the color-shape task.

Animacy Locomotion. Contingent on the cue presented, participants sorted a target (plane or rabbit) according to the animacy rule (living or nonliving) or the locomotion rule (flying or nonflying) by pressing the *D* (living or flying) or *K* (nonliving or nonflying) key. Cues for the animacy and locomotion rules were signified by images of dog paws and roads, respectively. All other methodological details were similar to the color-shape task.

Emotion Regulation Flexibility

Following Birk and Bonanno (2016), participants first completed a classic ER-implementation paradigm (e.g., McRae et al., 2012; Toh & Yang, 2022), which served to (a) train and familiarize participants in the ER strategies of reappraisal and distraction and (b) quantify how successful participants were in implementing reappraisal and distraction. Following this, the ER-choice task was administered. Pictorial stimuli, which were selected from the International Affective Picture System (Lang et al., 2008), did not significantly differ in valence and arousal across the ER-implementation (valence = 2.83, arousal = 5.20) and ER-choice tasks (valence = 2.72, arousal = 5.47), ts < 1.07, ps > .288.

Emotion-Regulation Implementation. In every trial of the ER-implementation paradigm (i.e., training phase), participants first saw a fixation point (1 s), followed by one of

three instruction words (“Reframe,” “Distract,” “Look”) for 2 s: (a) “Reframe” involves the use of reappraisal by imagining how the situation in the target picture would change for the better or identifying aspects of the situation that are not as bad as they seem; (b) “Distract” requires the use of distraction by shifting attention from a more negatively valenced target picture to neutral pictures located at the four corners of the screen; or (c) “Look” entails viewing the target picture naturally. Next, the target picture was presented in the center of the screen (11 s), and participants rated their negative emotions at the end of each trial (“How negative do you feel?” 1 = *not at all*, 7 = *very negative*). The intertrial interval, a screen that read “Relax,” varied between 1 and 3 s. There were 15 trials for each condition, presented in a randomized order: look instruction with neutral pictures, look instruction with negative pictures, reframe instruction with negative pictures, and distract instruction with negative pictures.

We conducted two manipulation checks to assess whether the unpleasant pictures elicited negative emotions and whether participants engaged in the ER strategies of reappraisal and distraction. First, participants rated the negative pictures as more negative than the neutral pictures in the “Look” condition, $t(207) = 49.97$, $p < .001$, indicating that the unpleasant pictures were perceived as more negative than the baseline (neutral) pictures. Second, the negative pictures in the “Look” trials were rated more negatively than those in the “Reframe” and “Distract” trials, *t*s >12.25, *p*s < .001 (adjusted with Bonferroni correction), thereby suggesting that participants actively regulated their emotions during the “Reframe” and “Distract” trials.

Emotion-Regulation Choice. The ER-choice task was methodologically similar to the ER-implementation task, with the exception that participants could choose to maintain or switch strategies in the former but not the latter. Each trial began with a fixation point (1 s), followed by the instruction “Reframe” (2 s) and a target picture shown in the center of the screen (11 s). After

the first 5 s of the presentation of the target picture, participants heard a tone (100 ms) which signaled that they could switch to distraction (by pressing the spacebar) or continue using reappraisal (not pressing the spacebar). If participants chose to change ER strategies, then the target picture would be surrounded by four (identical) neutral images for the reminder of the trial (up to 6 s depending on when the spacebar was pressed), which allowed for participants to attend to the neutral pictures instead of the central negative picture. If participants chose to continue engaging in reappraisal, then the target picture remained on the screen (6 s). At the end of each trial, participants reported their experienced emotions ("How negative do you feel?" 1 = *not at all*, 7 = *very negative*). The intertrial interval, a screen that read "Relax," varied between 1 and 3 s. There were 30 trials, and the target pictures were either low (15 trials; valence = 3.41; arousal = 5.01) or high negative intensity (15 trials; valence = 2.02; arousal = 5.93) presented in a randomized order.

Following Birk and Bonanno (2016), we excluded participants (n = 30) who showed no variation in strategy switching (i.e., either did not switch at all or switched all the time). We conducted a preliminary check on whether the different contextual demands elicited correspondingly varying degrees of strategy switching. As expected, the frequency of reappraisal-to-distraction strategy switching was higher for the high-intensity (M = 0.48, SD = 0.21) than the low intensity (M = 0.12, SD = 0.19) negative images, $t(177) = 23.48$, $p < .001$, which is consistent with past findings indicating that reappraisal and distraction are preferred for low- and high-negative intensity levels, respectively (Scheibe et al., 2015; Sheppes et al., 2011). The main variables of interest were the frequency (i.e., proportion) of strategy switching for the low-intensity and high-intensity conditions. For interpretative purposes, data were recoded such

that higher values in the low-intensity and high-intensity conditions represented a greater frequency of strategy maintenance and switching, respectively.

Covariates

Depressive symptoms were assessed using a short form of the Center for Epidemiological Studies-Depression survey (CES-D-10; Andresen et al., 1994). Participants responded to 10 items related to depressive symptoms experienced in the past week (e.g., “I felt depressed”; 1 = *rarely or none of the time*, 4 = *most of the time*), in which higher scores corresponded to greater depressive symptoms.

Reappraisal ability and distraction ability were indexed using the ER-implementation task (McRae et al., 2012), which was administered during the training phase (see previous section on Emotion Regulation Flexibility for further details). Lower ratings for the negative pictures in the “Reframe” condition and “Distract” condition, relative to the negative picture ratings in the “Look” condition, indicated more successful reappraisal and distraction, respectively. Residualized scores, computed by regressing mean ratings for the “Reframe” condition and the “Distract” condition on those for the “Look” condition, were coded such that higher scores signified better reappraisal ability and distraction ability, respectively. Demographic data (e.g., gender) were extracted using a background questionnaire.

Binning Procedure

Bin scores were used to index performance on the shifting tasks because they afford higher reliability, validity, and sensitivity in the detection of larger effect sizes and factor coherence than reaction time (RT) or accuracy scores (Draheim et al., 2016; Hughes et al., 2014; Toh & Yang, 2022). Bin scores were calculated based on procedures delineated by Draheim et

al. (2016), as follows. First, at the within-subject level, trials that were (a) incorrect, (b) had RTs faster than 200 ms, or (c) had RTs that departed from each participant's mean by more than 3 *SD* were excluded. Next, each participant's mean RT for repeat trials was deducted from the RT of every accurate switch trial. Second, at the between subject level, all difference scores were rank ordered as a group with bin scores assigned from 1 (*fastest 10%*) to 10 (*slowest 10%*). Third, all inaccurate switch trials were given a bin score of 20. Fourth, for each participant, a single bin score was generated by averaging bin values for accurate and inaccurate switch trials. Finally, bin scores were reverse-coded such that higher values reflected better performance.

Procedure

Participants completed the study across two sessions, with a 1-day interval between sessions. In the first session, EF tasks were administered in the following order: keep-track, Stroop, animacy locomotion, and Corsi block-tapping tasks. The second session started with the ER-implementation task, followed by the ER-choice task. Subsequently, they completed a series of questionnaires, which included the CES-D-10 (i.e., depressive symptoms) and the demographics background questionnaire. After a 5-min break, participants completed EF tasks in the following order: antisaccade, color-shape, two-back, go/no-go, and magnitude-parity. To minimize practice effects and potential noise caused by different task orders, the sequence of EF tasks was fixed for each participant, with the condition that no two consecutive tasks tapped the same EF dimension (Miyake et al., 2000). The entire study lasted approximately 3.5 hr. The study was approved by Singapore Management University's Institutional Review Board.

Analysis Plan

All analyses were conducted on *Mplus* 8.5 (Muthén & Muthén, 2015) using full information maximum likelihood estimation. EF dimensions were modeled as exogenous latent factors. The indicators for inhibition were the antisaccade, go/no-go, and Stroop tasks. The indicators for working memory were the keep-track, two-back, and Corsi block-tapping tasks. The indicators for shifting were the magnitude-parity, animacy-locomotion, and color-shape tasks. For ER flexibility, switching frequency in high- and low-intensity conditions was modeled as endogenous manifest variables. The covariates of gender, depressive symptoms, reappraisal ability, and distraction ability were manifest variables.

To determine whether the indicators reflected their underlying latent constructs, confirmatory factor analysis was first performed to assess how well the measurement model fitted the data. Subsequently, structural equation modeling was conducted to assess the link between EF and the maintenance or switching of ER strategies. Specifically, our primary analytic interests were twofold. First, we examined the relationships of each independent EF dimension (i.e., inhibition, working memory, and shifting) to both maintenance frequency in the low-intensity condition and switching frequency in the high-intensity condition (Models 1–3). Second, we examined whether the shared (i.e., common EF) and unique (i.e., working-memory-specific and shifting-specific factors) components, based on the second-order factor modeling approach, would be related to maintenance and switching frequency with respect to low- and high-intensity conditions (Model 4). In the second-order EF model, the second-order common EF factor represented the shared variance among the three first-order EF factors (i.e., working memory, inhibition, and shifting), whereas the disturbances (i.e., unique variances that are not explained by the common EF factor) for the working-memory and shifting factors signified working-memory-specific and shifting-specific processes, respectively (see Figures 1 and 2).

Next, we added the covariates (i.e., gender, depressive symptoms, reappraisal ability, and distraction ability) to examine whether the relations between EF and ER strategy maintenance/switching would still hold when covariates were controlled for. Following recommendations by Hair et al. (2009) and Hu and Bentler (1998), we adopted the following model-fit criteria: root mean square error of approximation (RMSEA) values equal to or lower than 0.08 (acceptable) or 0.06 (good); standardized root mean squared residual (SRMR) values equal to or lower than 0.08 (good); comparative fit index (CFI) close to or greater than 0.95 (good); and lower values for Akaike information criterion (AIC) and Bayesian information criterion (BIC) indicating better model fit.

Results

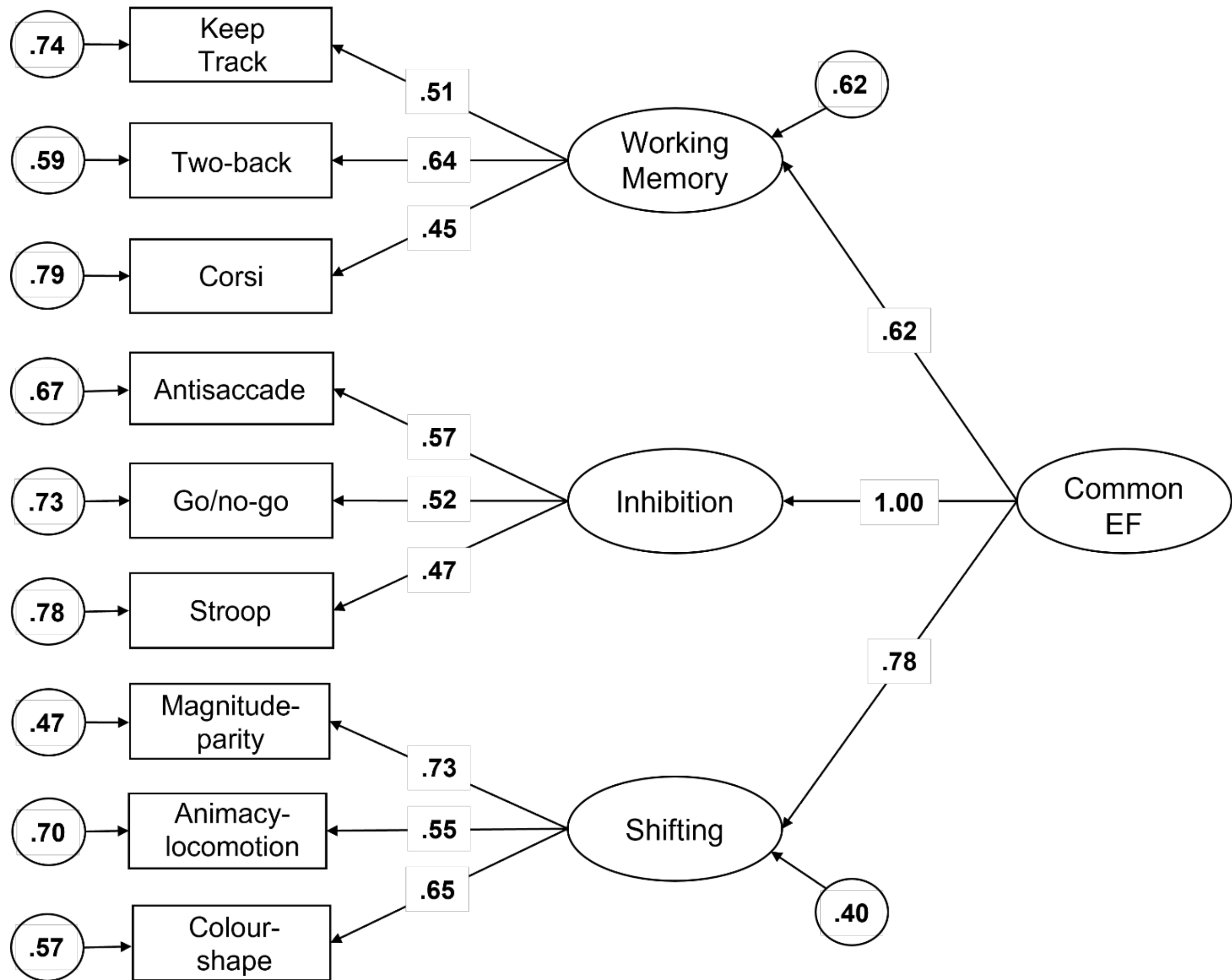
Measurement Model

Confirmatory factor analyses indicated that the second-order EF model had a good fit to the data (see Table 2), and all factor loadings were significant (ps < .001; see Figure 1). Consistent with prior research (Friedman et al., 2008), the first-order inhibition factor was perfectly explained ($\gamma = 1.00$) by the second-order common EF factor with no leftover disturbances, which denoted the absence of an inhibition-specific factor. Furthermore, despite the sizable factor loadings (γs = 0.62–0.78, ps < .001), disturbances for the first order working-memory and shifting factors were substantial and statistically significant (ζs = 0.40–0.62, ps < .002), thereby indicating working-memory-specific and shifting-specific processes above and beyond the common EF factor. We also compared the model fit of the second-order EF model to alternative EF models using Bayesian hypothesis testing (Wagenmakers, 2007), whereby higher Bayes factor (BF_{10}) values reflected greater evidence for the alternative hypothesis (i.e., second-order factor model) over the null hypothesis (i.e., one-, two-, and three-factor models). Crucially,

results indicated that the second-order factor model provided a better fit to the data over the one-, two-, and three-factor models ($BF_{10} > 4.55$; see Table 2). In essence, findings from the confirmatory factor analyses support the factor structure of the second-order EF model.

Figure 1

Second-order Executive Function Model with Standardized Estimates



Note. Ovals represent latent factors and rectangles denote indicators (i.e., manifest variables). Values on the longer, single-headed arrows correspond to factor loadings and values within the circles accompanied by the shorter, single-headed arrows signify residual variances or disturbances for the manifest variables or latent factors. All parameter estimates were statistically significant ($ps < .002$). EF = executive function.

Table 2

Fit Indices for Executive Function Measurement Model

	χ^2	*df*	RMSEA	SRMR	CFI	AIC	BIC	BF_{10}
One-factor model	56.80	27	.073	.061	.884	2399.01	2489.12	26199.62
Two-factor models								
Inhibition-WM merged	40.02	26	.051	.053	.945	2384.24	2477.69	86.19
Inhibition-shifting merged	34.14	26	.039	.046	.968	2378.36	2471.81	4.55
WM-shifting merged	56.17	26	.075	.061	.882	2400.39	2493.84	277062.95
Three-correlated-factors model	23.71	24	.000	.037	1.00	2371.93	2472.05	5.15
Second-order factor model	25.77	25	.012	.039	.997	2371.99	2468.78	–

Note. WM = working memory; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; CFI = comparative fit index; AIC = Akaike information criterion; BIC = Bayesian information criterion; BF_{10} = Bayes factor in favor of the alternative hypothesis (i.e., second-order factor model) over the null hypothesis (i.e., one-, two-, and three-factors models). Based on the classification scheme by Raftery (1995), we interpreted BF_{10} values as follows: weak evidence (BF_{10} between 1 to 3), positive evidence (BF_{10} between 3 to 20), strong evidence (BF_{10} between 20 to 150), and very strong evidence (BF_{10} of 150 and above).

Table 3

Fit Indices for Structural Models

	χ^2	*df*	RMSEA	SRMR	CFI	AIC	BIC
Model 1 (working memory)							
Unadjusted model	1.88	4	.000	.023	1.00	232.72	286.12
Adjusted model[a]	12.58	12	.015	.030	.994	2041.30	2181.47
Model 2 (inhibition)							
Unadjusted model	4.90	4	.033	.024	.990	-833.66	-780.26
Adjusted model[a]	8.31	12	.000	.021	1.00	971.52	1111.70
Model 3 (shifting)							
Unadjusted model	10.49	4	.088	.047	.962	2508.81	2562.21
Adjusted model[a]	14.08	12	.029	.031	.988	4314.15	4454.33
Model 4 (second-order factor model)							
Unadjusted model	43.14	37	.028	.043	.982	2177.10	2310.61
Adjusted model[a]	61.49	61	.006	.039	.999	3990.80	4237.78

Note. RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; CFI = comparative fit index; AIC = Akaike information criterion; BIC = Bayesian information criterion.
[a] Adjusted models included gender, depressive symptoms, reappraisal ability, and distraction ability as covariates.

Structural Models

We proceeded with structural equation modeling to test the links between EF and ER strategy-maintenance and strategy-switching frequency in low- and high-intensity contexts. All structural models provided acceptable to good fit to the data (see Table 3); standardized parameter estimates are shown in Table 4. When the three EF facets were assessed individually in the high-intensity condition, better working memory (unadjusted: $\gamma = .20$, $SE = .10$, $p = .046$; adjusted: $\gamma = .24$, $SE = .10$, $p = .020$) and shifting (unadjusted: $\gamma = -.27$, $SE = .09$, $p = .004$; adjusted: $\gamma = -.27$, $SE = .10$, $p = .007$)—but not inhibition ($|\gamma|$s $< .17$, ps $> .12$)—were concomitant with higher and lower frequency of reappraisal-to-distraction switching, respectively. In the low-intensity condition, however, better inhibition (unadjusted: $\gamma = .38$, $SE = .10$, $p < .001$; adjusted: $\gamma = .38$, $SE = .10$, $p < .001$) and shifting (unadjusted: $\gamma = .43$, SE =. 09, $p < .001$; adjusted: $\gamma = .43$, $SE = .10$, $p < .001$) were related to greater strategy-maintenance frequency. Working memory was not linked to strategy-maintenance frequency in the low-intensity condition ($|\gamma|$s $< .06$, ps $> .52$). The findings from the independent assessment of EF factors suggest that higher working memory is implicated in more frequent ER strategy switching (for the high-intensity condition), whereas higher inhibition (for the low-intensity condition) and shifting (for both high- and low-intensity conditions) are responsible for more frequent strategy maintenance.

For the second-order EF model, greater working-memory-specific ability was associated with more frequent strategy switching in the high-intensity condition (unadjusted: $\gamma = .36$, *SE* $= .12$, $p = .003$; adjusted: $\gamma = .37$, *SE* $= .13$, $p = .004$; see Figure 2). Common EF and shifting-specific factors were not related to switching frequency for the high-intensity condition ($|\gamma|$s $< .19$, ps $> .07$). In addition, we found that better common EF—but not working-memory-specific or shifting-specific factors ($|\gamma|$s $< .23$, ps $> .11$)—was linked to higher frequency of maintaining reappraisal as an ER strategy for the low-intensity condition (unadjusted: $\gamma = .38$, *SE* $= .10$, $p < .001$; adjusted: $\gamma = .38$, *SE* $= .10$, $p < .001$). Critically, results from the second-order factor model qualified the findings when each EF factor was individually examined. In particular, individuals with more proficient working-memory-specific ability showed greater tendency to switch from reappraisal to distraction in high-intensity situations[1], while common EF—and not shifting-specific processes—was primarily involved in the maintenance of ER strategies in low-intensity contexts.

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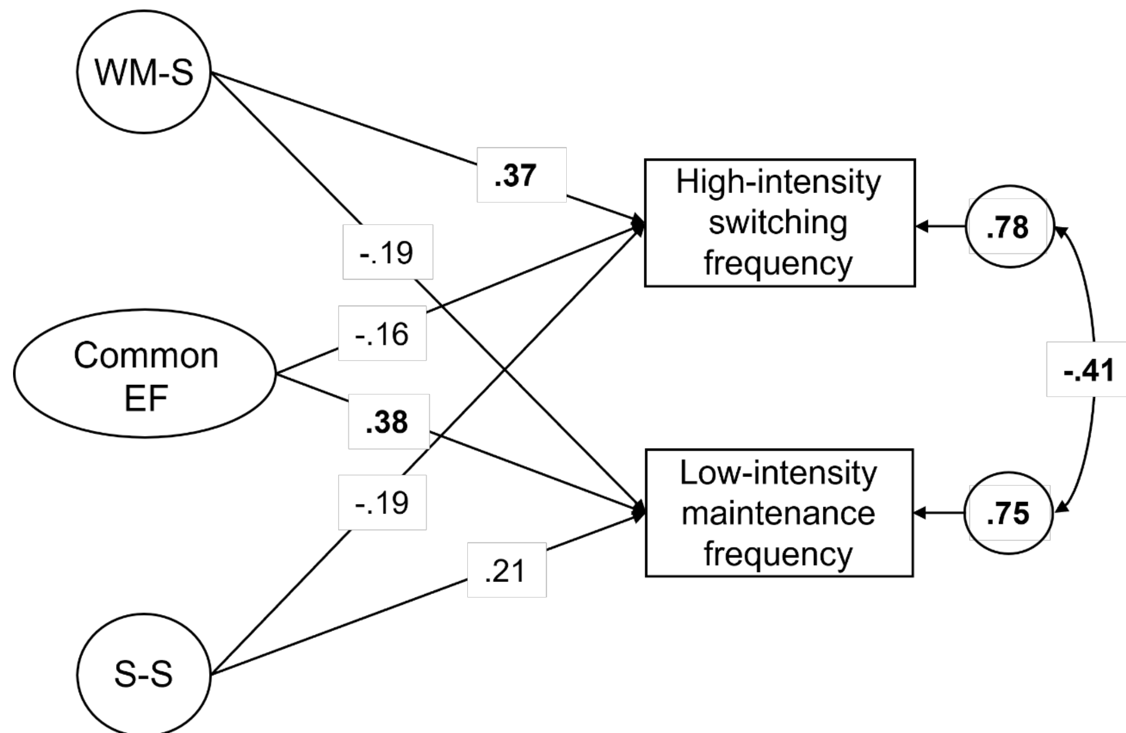
[1] It is notable that the relation between working-memory-specific ability and strategy-switching frequency remained unchanged when other performance indices, such as strategy-switching variability (i.e., standard deviation of the overall proportion of strategy switching frequency across low- and high-intensity conditions), were employed. Specifically, better working-memory-specific, but not common EF or shifting-specific ($|\gamma|$s $< .12$, ps $> .43$), ability corresponded to higher strategy-switching variability (γs $> .34$, ps $< .008$).

Figure 2

Structural Model of Executive Function Predicting Strategy-Maintenance and Strategy-Switching Frequency in Low-Intensity and High-Intensity Conditions



Note. Covariates and factor indicators are not shown for concision. Ovals represent latent variables, circles signify disturbances or residual variances, and rectangles indicate manifest variables. Common EF factor denotes the shared variance among the first-order latent factors (i.e., inhibition, working memory, and shifting), whereas working-memory-specific and shifting-specific factors represent the unique variances (i.e., disturbances) of first-order working-memory and shifting factors. Parameter estimates are standardized, and statistically significant values are shown in boldface ($p < .05$). Values on the longer, single-headed arrows denote path coefficients; values within circles accompanied by the shorter, single-headed arrows reflect residual variances; and values on the curved arrows correspond to residual correlations. WM-S = working-memory specific factor; EF = executive function; S-S = shifting-specific factor.

Table 4

Parameter Estimates for Structural Models Predicting Strategy-Maintenance and Strategy-Switching Frequency

	Low-intensity strategy-maintenance frequency		High-intensity strategy-switching frequency	
	Unadjusted	Adjusted	Unadjusted	Adjusted
Model 1				
Focal predictor				
Working memory	.06 (.10)	.03 (.11)	**.20 (.10)**	**.24 (.10)**
Covariates				
Gender	-	.04 (.08)	-	-.14 (.08)
Depressive symptoms	-	.04 (.08)	-	.02 (.08)
Reappraisal ability	-	.01 (.08)	-	-.07 (.08)
Distraction ability	-	**.18 (.08)**	-	-.07 (.08)
Model 2				
Focal predictor				
Inhibition	**.38 (.10)**	**.38 (.10)**	-.17 (.11)	-.16 (.11)
Covariates				
Gender	-	.01 (.08)	-	-.13 (.08)
Depressive symptoms	-	.08 (.08)	-	-.03 (.08)
Reappraisal ability	-	-.06 (.08)	-	-.02 (.08)
Distraction ability	-	.15 (.08)	-	-.01 (.08)
Model 3				
Focal predictor				
Shifting	**.43 (.09)**	**.43 (.10)**	**-.27 (.09)**	**-.27 (.10)**
Covariates				
Gender	-	-.01 (.07)	-	-.11 (.08)
Depressive symptoms	-	.08 (.07)	-	-.04 (.08)
Reappraisal ability	-	.02 (.07)	-	-.05 (.08)
Distraction ability	-	.10 (.08)	-	.03 (.08)
Model 4				
Focal predictors				
WM-specific	-.17 (.13)	-.19 (.13)	**.36 (.12)**	**.37 (.13)**
Common EF	**.38 (.10)**	**.38 (.10)**	-.19 (.10)	-.16 (.11)
Shifting-specific	.23 (.14)	.21 (.16)	-.19 (.15)	-.19 (.16)
Covariates				
Gender	-	-.02 (.08)	-	-.09 (.08)
Depressive symptoms	-	.07 (.08)	-	-.01 (.08)

Reappraisal ability	-	-.01 (.10)	-	-.05 (.10)
Distraction ability	-	.13 (.08)	-	-.02 (.09)

Note. WM = working memory; EF = executive function. Values denote standardized estimates with standard errors in parentheses. Significant values are marked in boldface, *p* <.05.

Discussion

The results from this study indicate that different aspects of EF support ER strategy maintenance and switching across low- and high-intensity environments. Our findings are noteworthy in several respects. First, we found that better working-memory-specific ability was concomitant with greater reappraisal-to-distraction switching frequency for high-intensity contexts (Model 4). Corroborating the role of working memory in ER strategy switching, as postulated by the cognitive-control framework of ER flexibility (Pruessner et al., 2020), our findings suggest that ER strategy switching entails the manipulation and updating of working-memory contents by replacing no-longer-relevant material with newer, more relevant information regarding the to-be-implemented ER strategy. These findings indicate that processes unique to working memory (i.e., updating contents within a mental workspace) facilitate ER flexibility and dovetails, in part, with prior work that underscores the integral contribution of working memory to cognitive flexibility (Blackwell et al., 2009) and theoretical accounts that emphasize the mechanistic role of working memory in the stability- flexibility tradeoff (Dreisbach & Fröber, 2019). However, our findings are silent on the mechanisms by which working memory promotes strategy switching, which may include removing and introducing no-longer-relevant and relevant ER strategies, respectively, within a mental workspace; keeping track of current and desired emotional states; and evaluating the effectiveness of the ongoing

strategy approach on emotional experiences. To this end, future studies should investigate the hypothesized mechanisms that underlie the relation between working memory and ER flexibility.

Second, we found that common EF, but not working-memory-specific, ability was principally implicated in the frequency of strategy maintenance—specifically, reappraisal—in low-intensity negative contexts (Model 4). For low-intensity negative situations, common EF—as a general goal-management ability—supports the stability mode of control (Dreisbach & Fröber, 2019), which involves implementing and maintaining ongoing ER strategies and tactics, thereby corroborating the critical role of EF in sustaining ER goals and processes (Toh & Yang, 2022). Additionally, our exploratory analyses suggest that individuals who more frequently switch strategies, relative to those who were more likely to retain reappraisal as an ER strategy, reported higher negative affect in the low-intensity condition (see "Appendix"). In line with the literature on how lapses in sustained attention and goal maintenance are linked to poor impulse control (Friedman et al., 2020), our finding suggests that lower common EF may be symptomatic of haphazard and premature strategy switching that prevents the maintenance of an initially implemented—and possibly effective—ER strategy (Sheppes et al., 2015).

While inconsistent with the cognitive-control framework of ER flexibility (Pruessner et al., 2020), the null relations of working memory (Model 1) and working-memory-specific (Model 4) abilities with strategy-maintenance frequency cohere with our speculation that working-memory-specific processes are not necessary for strategy maintenance. Notably, the ability to focus on, and sustain, relevant ER goals and information within a mental workspace, as hypothesized by Pruessner et al. (2020), is more characteristic of goal-maintenance and attention-control processes (i.e., common EF) that are pivotal to working-memory performance (Engle & Kane, 2004). Critically, it is notable that working-memory-specific and common EF

factors are uniquely associated with the decision to switch or maintain ER strategies, respectively, above and beyond third-variable effects, such as gender, depressive symptoms, and—more importantly—reappraisal and distraction ability (i.e., how successful one is in reframing, or diverting attention away from, affective content). Together, our findings underscore the importance of assessing EF as a multidimensional construct by demonstrating that different EF facets are divergently related to ER maintenance and switching frequency.

Despite the positive findings, some of the hypothesized associations of EF dimensions with strategy-maintenance and strategy-switching frequency were not supported. For instance, we found that neither common EF nor inhibition was related to strategy-switching frequency in high-intensity contexts (Models 2 and 4). For high-intensity situations, it is plausible that contextual demands influence mental gear-shifting operations that promote switching to a more situationally appropriate ER strategy (i.e., distraction), which in turn overrides the common EF processes involved in the maintenance of the initial ER strategy (i.e., reappraisal). Moreover, it is likely that the inhibitory processes assessed in our study (i.e., the ability to resolve interference from prepotent responses) are not specifically involved in ER strategy switching. Specifically, our ER-choice paradigm requires engagement with a predetermined ER strategy (i.e., reappraisal) that may not be the habitual or dominant ER strategy for every individual (Suri et al., 2015). Consequently, switching to a subsequent strategy (i.e., distraction) may not entail inhibiting a prepotent tendency to sustain the initial strategy (i.e., reappraisal). Furthermore, given the multifarious nature of inhibitory processes (Friedman & Miyake, 2004), it remains unknown whether other forms of inhibition, such as proactive interference (i.e., suppressing memory intrusions from no-longer-relevant information), could be linked to ER-strategy choice. Therefore, future research should employ ER-choice paradigms that more closely align with the

specific type of inhibition being studied and identify which inhibitory operation(s) is/are implicated in ER flexibility.

Disconfirming our hypothesis, as well as those from the cognitive-control framework of ER flexibility (Pruessner et al., 2020), we also found that strategy-switching frequency does not involve shifting or shifting-specific abilities. Our findings indicate that higher shifting—when assessed independently from other EF facets—was associated with a lower likelihood of ER strategy maintenance in both low- and high-intensity situations (Model 3). Importantly, findings from the second-order factor model clarified that the link between shifting and ER strategy maintenance was driven by common EF, but not shifting-specific, processes (Model 4). These results demonstrate that disregarding the common EF component could lead to misleading conclusions, thereby emphasizing the utility of decomposing EF into shared and unique components, which offers theoretical and empirical precision in understanding how EF components are linked to strategy maintenance and switching (see also Toh & Yang, 2022). We conjecture that while ER strategy switching involves replacing an existing strategy with a preferred one, it may not necessarily reflect the continuous switching between multiple mental sets that is representative of shifting abilities as assessed by task-switching paradigms (Monsell, 2003). Rather, during ER strategy switching, once a desired strategy has been chosen, further switches are unlikely. Hence, compared with working memory, ER strategy switching does not seem to involve extensive shifting abilities. Nevertheless, further replications of our work are needed to confirm these speculations.

Several limitations of the study should be noted. First, although reappraisal and distraction are the most commonly examined ER strategies in the ER flexibility literature (e.g., Birk & Bonanno, 2016; Sheppes et al., 2014), the links between EF and the flexible

implementation of other ER strategies are unknown. Notably, individuals employ an average of four ER strategies on a daily basis (Eldesouky & English, 2018), and certain types of ER strategies are habitually used by some individuals more than others (e.g., reappraisal, situation selection, and distraction; Guassi-Moreira et al., 2021). Furthermore, the self-reported negative emotions elicited by the affective stimuli employed in our study may not necessarily correspond to those generated via other media types (e.g., music and films) or daily experiences, which likely differ in personal relevance and ecological validity (Ellard et al., 2012; Rottenberg et al., 2007). Therefore, it remains to be seen whether similar patterns of results would be obtained using other emotion-eliciting stimuli or modes of assessment (e.g., experience-sampling methods). In this regard, future work would benefit from more comprehensive, multimodal assessments of ER strategies to obtain richer profiles of how individuals flexibly employ ER strategies across fluctuating situations.

Second, our results can only speak to the relations between EF and ER strategy switching from reappraisal to distraction. An alternative account of our findings is that EF predicts the general, nonspecific switching from an initial ER strategy to a subsequent one. Since we only tested reappraisal-to-distraction (but not distraction-to-reappraisal) strategy switching, we are unable to definitively examine this possibility. However, it should be noted that distraction-to-reappraisal switching reflects a nonoptimal strategy (Birk & Bonanno, 2016), owing to conflicting motivations in the desire to (a) switch strategies when one's negative affect has not been sufficiently reduced by distraction and (b) continue using distraction for high-intensity negative situations, given that it is less cognitively taxing and more adaptive than reappraisal under such circumstances (e.g., Levy-Gigi et al., 2016). Similarly, distraction-to-reappraisal switching has been shown to be unrelated to emotional intensity (i.e., the frequency of strategy

switching does not differ between low- and high-intensity conditions) as well as individual-difference factors, such as responsiveness to feedback from internal states (e.g., corrugator activity, heart rate deceleration) and well-being (Birk & Bonanno, 2016). Therefore, it seems unlikely that distraction-to-reappraisal switching would be associated with individual differences in EF abilities. Nevertheless, future research should ascertain whether EF would be more strongly related to the more optimal reappraisal-to-distraction condition than the suboptimal distraction-to-reappraisal condition.

Third, because our study focused on strategy-maintenance and strategy-switching frequency, our findings are unable to illuminate the associations between EF facets and monitoring processes (i.e., the continuous monitoring of potential discrepancies between regulatory efforts and changing contextual goals) that are involved in ER flexibility (Pruessner et al., 2020). According to the cognitive-control framework of ER flexibility, working memory facilitates ER monitoring processes by lowering the updating threshold, thereby allowing for new information and contextual fluctuations to be more easily detected (Pruessner et al., 2020). However, considering that effective monitoring would inform the decision to modify the existing regulatory approach as required (e.g., maintaining or switching strategies), our findings demonstrating the link between working-memory-specific ability and strategy-switching frequency (Model 4) may reflect, in part, the contribution of working-memory-specific ability toward monitoring processes. Therefore, the question of how EF would be associated with the ability to monitor and utilize feedback from ongoing regulatory efforts to guide strategy maintenance/switching is an important one that deserves further empirical investigation.

Fourth, given that our study focused on the role of EF in ER strategy maintenance/switching frequency, our findings are agnostic to the adaptiveness or effectiveness

of ER flexibility. While our exploratory analyses suggest that more proficient common EF and higher strategy-maintenance frequency are related to lower postchoice negative affect ratings (reported at the end of each trial) in the ER-choice task (see Appendix), we urge caution against drawing definitive conclusions from these findings because we did not collect prechoice negative affect (see also Dorman-Ilan et al., 2019). Notably, given that postchoice ratings capture both (a) prechoice negative affect (baseline) and (b) pre- to postchoice changes in negative affect, it is unclear whether the observed associations of EF and ER-strategy frequency with postchoice ratings are driven by changes from pre- to postchoice negative affect or prechoice negative affect. Our a priori decision to not collect prechoice ratings was due to concerns that repeated assessments of explicit self-reported affect could potentially bias emotional responding (Dorman-Ilan et al., 2019; Rottenberg et al., 2007). Given that frequency and effectiveness (or success) are important markers of ER processes that differentially predict behavioral outcomes (Guassi-Moreira et al., 2022; McRae, 2013; McRae et al., 2012), future research incorporating prechoice and postchoice indicators of emotional responding (e.g., cortisol levels, heart rate, etc.) is needed to evaluate the link between EF and the adaptiveness of ER flexibility.

In summary, our study contributes to the burgeoning empirical interest in ER flexibility by delineating how EF facets are linked to ER strategy maintenance and switching across different emotional contexts. Using a latent-variable approach to partition the common and unique components of EF, our findings show that the flexible switching of ER strategies principally entails the working-memory-specific ability to manipulate and update affective information within a mental workspace, whereas strategy maintenance predominantly recruits the common EF ability to activate and maintain ER goals in low-intensity situations. Importantly, our results provide an initial test of the cognitive-control framework of ER

flexibility (Pruessner et al., 2020) and positions EF as a critical cognitive factor that biases ER strategy choice in accord with environmental demands.

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Appendix

While our a priori research goals focused on the role of EF in strategy maintenance and switching *frequency*, we conducted several exploratory analyses on the *effectiveness* (or success) of regulatory decisions using the self-reported negative affect ratings in the ER-choice task.

First, we assessed whether EF would be related to emotional experiences in which participants maintained or switched strategies across different affective intensities (Model 5). To achieve this, we regressed the negative affect ratings of trials in which participants maintained and switched strategies for the low-intensity and high-intensity conditions on the three EF facets (i.e., common EF, working-memory-specific, and shifting-specific abilities). Additionally, we controlled for the same set of covariates as our main analyses (i.e., reappraisal ability, distraction ability, gender, and depressive symptoms). Results indicated that higher common EF was concomitant with lower negative affect ratings for trials in which participants maintained the pre-existing regulatory approach (i.e., reappraisal) in both the low-intensity ($\gamma = -.28$, $SE = .09$, $p = .002$) and high-intensity ($\gamma = -.20$, $SE = .10$, $p = .037$) conditions, above and beyond the ability to successfully implement ER strategies (i.e., reappraisal and distraction). No other associations between EF and negative affect ratings were found.

Second, we examined whether the frequency of strategy maintenance and switching would be associated with negative affect experiences (Model 6). Specifically, we regressed mean negative affect ratings for both the low-intensity and high-intensity conditions on the frequencies of strategy maintenance and switching for the low-intensity and high-intensity conditions, while controlling for covariates (i.e., reappraisal ability, distraction ability, gender, and depressive symptoms). We found that lower frequency of strategy maintenance (i.e., higher frequency of strategy switching) was associated with higher self-reported negative affect for the low-intensity

condition ($\gamma = -.22$, $SE = .05$, $p < .001$), thereby suggesting that frequent premature strategy switching in contexts that favor strategy maintenance may be suboptimal. However, strategy-switching frequency was not related to negative affect in the high-intensity condition (which promotes reappraisal-to-distraction switching). Given that postchoice ratings capture both prechoice affect and changes from pre- to postchoice affect, the null relation between strategy-switching frequency and postchoice negative affect in high-intensity contexts can be explained by two opposing effects that counteract each other. Specifically, strategy-switching frequency would be *positively* related to prechoice negative affect (because heightened prechoice negative affect increase the tendency to switch strategies; Birk & Bonanno, 2016), but *negatively* associated with changes in pre- to postchoice negative affect (as switching strategies would potentially decrease negative affect). Therefore, future studies that include pre- and postchoice indicators of emotional experiences are needed to properly elucidate the effectiveness of regulatory decisions.

Third, we explored the interaction effect of EF and frequency of strategy maintenance/switching on negative affect (Model 7). To this end, we included EF (i.e., common EF, working-memory-specific, and shifting-specific abilities) and all possible interactions involving the three EF components with the frequency of strategy maintenance and switching for the low-intensity and high-intensity conditions to Model 6. None of the interaction terms between the EF facets and strategy maintenance/switching frequency were consistently significant for both the low-intensity and high-intensity conditions. Therefore, our findings do not demonstrate evidence for any interactive effects of EF and frequency of strategy maintenance/switching on negative affect. However, it should be noted our model does not have sufficient statistical power to estimate the interaction effects (<38%) and, therefore, future

studies should employ larger sample sizes to investigate how EF interacts with strategy-maintenance and strategy-switching frequency.