The relationship between individual differences in executive functioning and emotion regulation: A comprehensive review

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Abstract

Research in cognitive psychology and cognitive neuroscience shows that the executive functions (particularly inhibition, updating, and shifting) form the core of higher-order thought processes in humans (including logical reasoning). Much less attention has been devoted to the role of the executive functions in emotional and motivational processes. The current chapter reviews research on the contributions of the executive functions to emotion regulation. The findings suggest that cognitive ability helps to shape human emotional life, but they also raise new questions about why this is so.

Emotion regulation is an important key to human social life. It is sufficiently important that several laws, rules, and social norms explicitly require people to regulate their emotions. For example, many nations including Brazil, Canada, and New Zealand have enacted “Hate Speech” laws to discourage inflammatory expressions of prejudice or hatred. More prosaically, Major League Baseball reserves the right to disqualify any player who expresses displeasure with an umpire’s decision (Rule 9.01d of the Official Rules of Major League Baseball). But even strong sanctions against emotional expression do not guarantee successful emotion regulation. Consider that legendary player and manager John McGraw expressed sufficient displeasure to be disqualified from 131 baseball games over the course his Hall-of-Fame career (James, 2001).

Emotion regulation is also central to psychological well-being. This is exemplified by the fact that abnormalities in emotion regulation are central to several forms of psychopathology, including mood and anxiety disorders (American Psychiatric Association, 1994). For example, students with generalized anxiety disorder report greater reactivity to emotional events and poorer ability to control emotions relative to non-disordered students (Mennin, Heimberg, Turk, & Fresco, 2005), and adults who report more difficulty with emotion regulation also report more anxiety, more worry, and more agoraphobic thoughts relative to other adults (Kashdan, Zvolensky, & McLeish, 2008). Conversely, better ability to control emotions has been associated with psychological well-being (Bonanno, Papa, Lalande, Westphal, & Coifman, 2004; Côté, Gyurak, & Levenson, 2010).

What contributes to success at emotion regulation? Previous research has identified personality traits such as conscientiousness (e.g., Jensen-Campbell, Knack, Waldrip, & Campbell, 2007) and agreeableness (e.g., Haas, Omura, Constable, & Canli, 2007; Tobin, Graziano, Vanman, & Tassinary, 2000) as major influences, along with self-esteem (e.g., Wood, Heimpel, & Michela, 2003) and individual differences in asymmetrical activation of the frontal hemispheres of the brain (e.g., Jackson et al., 2003; Urry et al., 2004); undoubtedly there are others. The present chapter examines the contributions of cognitive ability to success at emotion regulation. More precisely, we review evidence pertaining to the hypothesis that a suite of cognitive abilities known as the executive functions contribute to success at emotion regulation.

Executive functions

The executive functions are cognitive processes associated with the frontal lobes of the brain that help to coordinate and regulate other processes and brain regions. Although a definitive list of the executive functions does not yet exist, the usual suspects include the capacities for response inhibition, forming a plan and implementing it, switching back and forth between tasks, maintaining and updating memory representations, and resisting interference from distractors (see Hofmann, Schmeichel, & Baddeley, 2012).

In the current chapter we lean on seminal research by Miyake et al. (2000) regarding the underlying factor structure of performance on executive functioning tasks. In a large sample of college students who performed a battery of 9 putative executive functioning tasks, Miyake and colleagues found evidence for three related but empirically distinct executive functions: information updating and monitoring (“updating”), mental set shifting (“shifting”), and inhibition of pre-potent response (“inhibition”). Accordingly, in the current chapter we review evidence regarding the contributions of individual differences in updating, shifting, and inhibition to success at emotion regulation.

Ample research suggests that the executive functions and the brain structures that support them underlie performance on a host of complex cognitive or attentional tasks, including tasks that require logical reasoning (e.g., Copeland & Radvansky, 2004; Kyllonen & Christal, 1990), reading comprehension (e.g., Cain, Oakhill, & Bryant, 2004; Daneman & Carpenter, 1980), dual tasking (e.g., D'Esposito et al., 1995), goal maintenance (e.g., Kane & Engle, 2003), fluid intelligence (e.g., Engle, Tuholski, Laughlin, & Conway, 1999), and planning (e.g., Miyake et al., 2000). The consensus view is that the executive functions are central to human cognitive processing.

How about emotional processing? Do the executive functions contribute to human emotional life? Historically, research on the executive functions has been the province of cognitive psychology and cognitive neuroscience, and the bulk of the research in these areas has focused on identifying the structures and functions that underlie performance on laboratory tests of cognitive performance. For example, hundreds of studies in cognitive psychology have examined response inhibition using the Stroop task (see MacLeod, 1991), and numerous studies in cognitive neuroscience have found evidence for increased activation in the dorsolateral prefrontal cortex during tasks that require executive functioning, including overriding a predominant response (e.g., MacDonald, Cohen, Stenger, & Carter, 2000) and updating representation in working memory (e.g., Barbey, Koenigs, & Grafman, 2012; see Smith & Jonides, 1999).

Much less attention has been paid to possible relationships between the executive functions and emotional processes and responses. The research that has been done on this topic has tended to assess the impact of emotional states on executive functioning (for overviews, see Mueller, 2011, Pessoa, 2009). In the current chapter we review evidence pertaining to the converse form of influence, namely the influence of executive functions on emotional processes and responses, focusing especially on emotion regulation.

Why should the executive functions be related to emotion regulation? Inhibition is perhaps the most likely contributor. Inhibition involves overriding a predominant response tendency and has been widely studied by asking participants to try to stop a response that has been triggered by a task cue. Presumably this capacity for inhibitory control can also be applied to emotional responses, such as the subjective experience of emotion or the automatic facial expressions triggered by emotional stimuli (e.g., Dimberg, Thunberg, & Grunedal, 2002). On logical grounds, the executive function of updating is also likely to contribute to some forms of emotion regulation. Attempting to regulate emotions by thinking about events in different, relatively non-emotional ways would seem to require the capacity to replace initial appraisals of an emotional event with secondary, less emotional appraisals (or more emotional appraisals, if the goal is to increase emotional responding). Updating may also be required to maintain the goal to regulate emotion despite automatic response tendencies triggered by emotional events that could undermine the regulatory goal (Kalisch, 2009). Shifting also seems relevant to emotion regulation, insofar as moving between emotional and non-emotional mental sets helps to regulate emotion. However, as we shall see, the relationship between shifting and emotion regulation has received scant research attention.

Emotion Regulation

Because the executive functions are thought to coordinate and regulate other processes, we reasoned that the most obvious place to look for evidence of a relationship between the executive functions and emotions would be in research on emotion regulation. Emotion regulation refers to efforts to change the duration or intensity of an emotional response. For example, a spelling bee winner who hides her pride to spare the feelings of a competitor, an employee who feigns enthusiasm for a tedious task, and a test-taker who reinterprets his anxiety as eager anticipation engages in emotion regulation (for a review, see Koole, 2009).

Theorists have proposed two broad classes of emotion regulation attempts: those that occur prior to an emotional response (e.g., situation selection, bracing for an emotional event) and those that occur after an emotional response has been triggered (e.g., expressive suppression) (see Gross, 2007). The two most commonly studied emotion regulation strategies are expressive suppression and reappraisal. Expressive suppression refers to the inhibition of outward expressions of emotion and occurs after an emotional response has been triggered. Reappraisal refers to efforts to think differently about or to distance oneself mentally from an emotional event and can occur both before and after an emotional response has been triggered. The majority of the research reviewed in this chapter concerns success at emotion regulation in the form of expressive suppression and reappraisal.

Emotional responses and the regulation of emotional responses are often assumed to be distinct phenomena, although in practice these can be difficult to tease apart (see Gross, Sheppes, & Urry, 2011). In this chapter we adopt the convention of treating the generation of emotion and the regulation of emotion as distinct events, and we focus the bulk of our attention on the regulation of emotion. Our guiding assumption is that the generation of emotion is largely an automatic and nonconscious process, and is thus relatively unlikely to be influenced by executive functioning. By contrast, emotion regulation is assumed to be a relatively more controlled, conscious process that is more amenable to executive control.

What is and what's not reviewed in this chapter

Two strands of evidence are brought to bear on the question of whether the executive functions influence emotion regulation. First, we review research on individual differences in executive functioning and their relationship to emotion regulation. Simply put, some people are more adept than others at updating, shifting, and response inhibition. Do these individual differences in cognitive ability relate to emotion processes and responses? Second, we review experimental research that has tried to disrupt cognitive ability and assess the impact on emotional responding and emotion regulation, and we evaluate the implications of this evidence for considering the executive functions as causal determinants of success or failure at emotion regulation.

We have focused our review of individual differences research specifically on studies that have used behavioral (e.g., performance-based) measures of both executive functioning and emotion regulation ability, respectively. By focusing on performance-based measures we sought to minimize the possibility that any observed relationships are tainted by self-report biases or socially-desirable responding. Therefore, we do not review studies showing that self-reported executive functioning ability moderates success at emotion regulation (e.g., Derryberry & Reed, 2002; Gyurak & Ayduk, 2007; Jones, Fazio, & Vasey, 2012), or evidence that self-reported personality traits are associated with performance on executive functioning tasks (e.g., Bridgett, Oddi, Laake, Murdock, & Bachmann, 2012). Nor do we review evidence that has associated emotion regulation with non-executive cognitive abilities or atypical measures of executive functioning (e.g., Compton, 2000; Wilkowski, Robinson, & Troop-Gordon, 2010).

Furthermore, we do not review the substantial body of evidence assessing brain activation levels using fMRI during different types of emotion regulation tasks. The question of interest in this research has been which brain structures become more or less activated as a result of conscious efforts at emotion regulation (e.g., Beauregard, Lévesque, Bourgouin, 2001; Kalisch et al., 2005; Schaefer et al., 2002; see Ochsner & Gross, 2005, for an overview). The simplified answer is that when individuals try to down-regulate negative emotions, brain structures associated with executive functioning (e.g., dorsolateral prefrontal cortex, ventrolateral prefrontal cortex) become more activated whereas brain structures associated with emotional responding (e.g., amygdala, ventral striatum) become less activated. This pattern is particularly common in studies of the reappraisal of emotional stimuli (for reviews, see Kalisch, 2009; Ochsner, Silvers, & Buhle, 2012). Such evidence is consistent with the idea that the frontal lobes are an important key to success at emotion regulation but does not directly address the role of individual differences in executive functioning ability (though this is beginning to change; Winecoff, LaBar, Madden, Cabeza, & Huettel, 2011).

We also do not review evidence associating developmental changes from childhood to adulthood with changes in emotion regulation ability. It is well known that cognitive ability improves from childhood to adulthood, owing in part to maturation of frontal lobes (e.g., Casey, Tottenham, Liston, & Durston, 2005; Luna, Padmanabhan, & O'Hearn, 2010). Insofar as emotion regulation relies on executive functions associated with the frontal lobes, emotion regulation ability should improve in corresponding fashion. Research has begun to support for this view. For example, one fMRI study of cognitive reappraisal in participants ranging in age from 10 to 22 (McRae et al., 2012) found improvements in emotion regulation with age (see also Silvers et al., 2012) and further observed age-related increases in activation of the left ventrolateral prefrontal cortex and the left inferior frontal gyrus during reappraisal. As these regions have been observed to be activated during cognitive reappraisal in studies of adults (e.g., Goldin, McRae, Ramel, & Gross, 2008; Ochsner, Bunge, Gross, & Gabrieli, 2002), these results suggest that reappraisal ability improves with age in part due to increased recruitment of the frontal lobes during emotion regulation (see also Perlman & Pelphrey, 2011).

Individual Differences in Executive Functioning and their Relationship to Success at Emotion Regulation

In this section we provide what is intended to be a comprehensive review of published research on the extent to which individual differences in executive functioning predict success at emotion regulation. We identified and review below 11 articles describing 14 studies that met our inclusion criteria: performance-based measures of both executive functioning and emotion regulation, respectively. Please refer to Table 1 for an overview of these studies.

The first investigation into possible relationships between performance on behavioral measures of executive control and emotion regulation sampled children at 22 and 33 months of age (Kochanska, Murray, & Harlan, 2000). All the children completed an age-appropriate battery of tasks assessing their capacities to delay gratification, slow or suppress responding (e.g., walk down a line to and from the mother as slowly as possible), and focus attention. The children also experienced one positive and one negative emotional event that supplied the relevant measures of emotion regulation. The positive experience involved viewing a humorous puppet show and then being gently tickled by the puppets. The negative experience involved being strapped tightly into a car seat by the mother. The results revealed that children who scored higher on effortful control expressed less intense anger to the physical restraint challenge and less intense joy to the puppet show, relative to children who scored lower on effortful control. The authors interpreted these patterns as evidence that effortful control ability in children contributes to the successful regulation of approach-related emotional responses.

Another early examination of possible relationships between effortful control and emotion regulation sampled children aged 3 to 5 (Kieras, Tobin, Graziano, & Rothbart, 2005). All the children completed tasks that assessed their capacity to slow or suppress responding (e.g., drawing a line as slowly as possible). The children also rated several toys and books and later were videotaped as they received their top-rated toy. Then the children rated another set of books and toys before receiving their least favorite one; again their reactions were videotaped. Emotion regulation was quantified as the difference in positive emotional expressions upon receiving the more desirable versus the less desirable gift, with smaller differences revealing better emotion regulation (i.e., reduced display of socially-inappropriate displeasure). The results indicated that older children and children who scored better on the effortful control tasks exhibited smaller differences in positive emotional expression after receiving the desirable versus undesirable gifts, consistent with the idea that effortful control can help to override negative emotional reactions.

Do the relationships observed between effortful control and emotion in children hold up into adulthood? One of the first investigations into possible relationships between executive functioning and emotion regulation in adults looked for links between inhibitory control and the suppression of a socially inappropriate response (von Hippel & Gonsalkorale, 2005). Participants completed a Stroop task as a measure of individual differences in inhibitory ability. Then, in the crucial condition of the experiment, non-Asian participants were asked by a Chinese experimenter to taste a chicken foot, which had been described as the national dish of China. Participants' facial expressions and verbal utterances were recorded by a hidden video camera as the chicken foot was revelaed and were coded as expressing a negative, neutral, or positive response to the chicken foot. Consistent with the hypothesis that executive functioning contributes to success at emotion regulation, participants who performed better (more quickly) on the Stroop task exhibited less negative responses to the chicken foot, relative to participants who performed more poorly on the Stroop task.

A subsequent multi-study investigation used more traditional methods of emotion elicitation to assess the relationship between working memory capacity—an indicator of updating—and success at both expressive suppression and cognitive reappraisal, respectively (Schmeichel, Volokhov, & Demaree, 2008). In a first study participants completed a well-validated measure of working memory capacity known as the operation span task (OSPAN; Turner & Engle, 1989), which required them to recall word lists while solving math problems. Then they viewed a brief, highly aversive (disgusting) film clip under instructions to suppress all outward expressions of emotion. Participants' faces were videotaped as they viewed the film clip, and a trio of naïve judges later rated how emotionally expressive each face was. Scores on the working memory test predicted emotional expressiveness, such that participants with higher working memory capacity were rated as expressing less emotion on their faces. A second study found the same pattern among participants who had been instructed to suppress outward expressions of emotion during an amusing film clip. Further, working memory capacity was not associated with emotional expressiveness among participants who watched the amusing film in the absence of instructions to suppress. Together, these studies support the idea that working memory capacity contributes to successful suppression of both positive and negative facial expressions of emotion.

Schmeichel and colleagues (2008) also found evidence of a relationship between working memory capacity and success at reducing subjective emotional experience by adopting neutral, non-emotional appraisals of emotional stimuli. Participants in one study completed the OSPAN and then viewed a disgust-inducing film clip under instructions either to view the film clip naturally (express condition) or to adopt a detached, unemotional attitude and think about the film objectively (reappraisal condition). Following the film, all participants reported their current level of disgust. The neutral appraisal instructions resulted in successful emotion regulation, such that participants in the reappraisal condition reported less disgust compared to participants in the express condition. Further, working memory capacity moderated this effect, such that only participants with higher working memory capacity experienced less disgust in the reappraisal condition.

A final study in this series sought replicated this pattern using a different measure of working memory capacity, namely an n-back task, and using different emotion-laden film clips (one humorous and one sorrowful). Once again, participants with higher working memory capacity were more successful at reappraisal insofar as they reported more neutral emotional states and expressed less emotion on their faces, relative to participants lower in working memory capacity.

Altogether, the studies by Schmeichel et al. (2008) found that working memory capacity was important for success at two different forms of emotion regulation—expressive suppression and cognitive reappraisal—and was effective for the regulation of both positive and negative emotional stimuli. However, a more mundane explanation for those findings is possible, and this explanation applies to the bulk of the research on emotion regulation reviewed below. Specifically, because participants were instructed by the experimenter to regulate their emotional responses, the results of Schmeichel and colleagues may show simply that individuals with higher cognitive ability are better at following instructions. This explanation is consistent with evidence that WMC predicts success at following instructions in a classroom setting (Engle, Carullo, & Collins, 1991). The question arises, then, whether more successful emotion regulation among persons with better executive functioning is a simply a matter of being better at following instructions.

To address this question, Schmeichel and Demaree (2010) tested the hypothesis that working memory capacity contributes to spontaneous emotion regulation—emotion regulation not specifically instructed by the experimenter. After completing a measure of working memory capacity, participants in this study took a bogus personality test and received either negative feedback or no feedback about their personalities. A short while later, participants completed a test described as a new measure of crystallized intelligence. In fact, this test was the over-claiming questionnaire (OCQ), a disguised measure of self-enhancement tendencies developed by Paulhus, Harms, Bruce, and Lysy (2003).

The OCQ asks respondents to rate their familiarity with different book titles, scientific terms, historical figures, and other elements of cultural knowledge using a scale from 0 (*not at all familiar*) to 6 (*very familiar*). Embedded in the OCQ are several foil or fake items, and the outcome measure of interest is the proportion of foil or fake items with which participants claim familiarity. Based on previous evidence of defensive responding to threats to self-regard (e.g., Baumeister, Heatherton, & Tice, 1993; Greenberg & Pyszczynski, 1985), Schmeichel and Demaree (2010) predicted that receiving negative feedback would increase the motivation to self-enhance. The subsequent "crystallized intelligence test" (i.e., OCQ) gave participants the opportunity to act on this motivation by claiming familiarity with things that could not be familiar.

The evidence supported this prediction, but only among participants higher in working memory capacity. They over-claimed more than participants lower in working memory capacity. Consistent with greater success at emotion regulation, participants higher in working memory capacity also reported less negative affect at the end of the experiment, relative to participants lower in capacity. These results suggest that cognitive ability resources are recruited spontaneously to cope with threats to self-regard and control negative emotion. Further, because participants had not been instructed to regulate their emotional responses, the finding of less negative emotion among participants higher in working memory is not a simple reflection of following directions.

Another study by a different team of investigators replicated and extended the evidence that working memory capacity contributes to success at emotion regulation. McRae, Jacobs, Ray, John, and Gross (2012) measured several different cognitive abilities including working memory capacity, set-shifting ability, verbal ability, abstract reasoning, and inhibitory control, and then examined how each of these abilities relates to cognitive reappraisal. Success at reappraisal was quantified as the difference in self-reported responding to emotional pictures viewed under instructions simply to look at the pictures or to reappraise the pictures, with bigger differences reflecting better reappraisal. McRae et al. found that success at reappraisal was correlated with working memory capacity and with set-shifting ability, respectively, but success at reappraisal was not significantly associated with verbal ability, reasoning ability, or inhibitory control.

The study by McRae et al. (2012) is part of a modest spate of studies that have examined several different cognitive abilities and attempted to associate them with success at emotion regulation, with each study using a different measure of emotion regulation. The first such study tested a sample of 17 healthy adults and 31 adults with neurodegenerative brain disease (e.g., Alzheimer's disease; Gyurak et al., 2009). All participants completed a battery of cognitive tests including verbal and spatial measures of updating, the Stroop task to measure inhibition, the trail making test to measure shifting, and a measure of verbal fluency. Participants also experienced an emotionally-arousing event that yielded a measure of emotion regulation ability. Specifically, while looking at an "X" displayed on a television screen a startling burst of noise was played over loudspeakers strategically located behind the participant's head. The magnitude of the startle response to the noise burst was quantified by coding facial expressiveness during the 5 seconds following the startle noise and by tracking body movement with a sensor located under the participant's chair. Following the initial, unexpected noise burst, two more loud bursts of noise were played; one followed a warning of when the noise would occur, and one followed a warning plus instructions to suppress outward reactions to the noise.

The question of interest was whether any of the cognitive ability measures would predict the magnitudes of startle responses to the noise bursts. When the noise burst was unexpected (i.e., the initial noise), the answer was no; none of the cognitive measures in the study by Gyurak et al. (2009) predicted responding to the unexpected startle noise. However, after controlling for responding to the unexpected noise, participants with higher (versus lower) verbal fluency startled less when the noise burst was preceded by a warning. The same result was observed when assessing responding to loud noise preceded by a warning and instructions to suppress. Thus, verbal fluency predicted successful startle suppression, but working memory capacity, inhibitory control, and task-switching ability did not relate to startle responding to any of the noise blasts. This pattern of findings suggests that verbal ability, but perhaps not executive functioning more generally, is important for emotion regulation.

The same research group conducted a similar study, this time with a sample of 21 healthy older adults and 48 neurodegenerative patients (Gyurak, Goodkind, Kramer, Miller, & Levenson, 2012). The same cognitive measures as before were assessed (i.e., working memory, inhibitory control, task switching, and verbal fluency), but a different emotion regulation test was used. In this study participants watched three disgust-inducing film clips under instructions to watch, to down-regulate outward emotional responses, and to up-regulate emotional responses, respectively. Once again, verbal fluency was the only significant predictor of emotion regulation ability, which was quantified as a composite score reflecting changes in heart rate and facial expressions of emotion in the down-regulation and up-regulation conditions, respectively, controlling for responses in the watch condition. Here again, verbal ability but not executive functioning more generally predicted success at emotion regulation.

Does the predictive power of cognitive ability hold up outside the laboratory? One daily diary study including over 1000 adult participants found that the relationship between executive functioning and emotion regulation can indeed be observed in people's responses to daily life events (Stawski, Almeida, Lachman, Tun, & Rosnick, 2010). Participants in this study completed a phone-based measure of executive functioning that included tests of working memory capacity and verbal fluency, among other cognitive abilities. They also completed short interviews about their daily experiences and emotions on 8 consecutive days. Not surprisingly, participants reported more negative emotion on days in which they experienced a stressor. Of greater interest are the observed contributions of cognitive ability. Participants scoring higher on the executive functioning measure were more likely to report experiencing stressors relative to participants scoring lower on the executive functioning measure. (The severity of stressors did not vary as a function of executive functioning ability.) Furthermore, better executive functioning was associated with smaller stressor-related increases in negative mood. That is, although adults with higher cognitive ability experienced more daily hassles, they experienced smaller changes in mood in response to those hassles. These results provide novel support for the hypothesis that executive functioning helps to regulate emotional responding to stressors, and they provide compelling evidence that the contributions of executive functioning to emotion regulation exist outside the laboratory as well as in it.

One recent fMRI study tested the hypothesis that the same brain regions involved in the performance of classic cognitive tests of executive functioning are also invoked during emotion regulation. Specifically, Tabibnia and colleagues (2011) had healthy participants and methamphetamine-dependent participants complete a well-validated measure of inhibitory control (i.e., the stop signal task) as well as an emotion reappraisal task. Participants with better inhibitory control on the stop signal task were more successful at emotion regulation; they reported less negative emotion after viewing negative emotional images under instructions to reappraise. Further, in addition to worse inhibitory control and less success at emotion regulation, methamphetamine-dependent participants had less gray matter density in the right inferior frontal gyrus, suggesting that this region underlies performance at both the executive functioning and emotion regulation tasks.

We are aware of just one additional article assessing the relationship between executive functioning and success at emotion regulation. Building on evidence that the experience of disgust increases the severity of moral judgments unrelated to the source of the disgust (e.g., Schnall, Haidt, Clore, & Jordan, 2008), Van Dillen, van Wal, and van der Bos (2012) tested the extent to which individual differences in executive functioning moderate the effect of disgust on moral judgments. They found that disgust increased the severity of moral judgments, but only among participants with poorer executive functioning (as measured by the Stroop task in Study 1 or by self-report measures of attention control in Studies 2 and 3). Participants with better executive functioning did not render more severe moral judgments following the induction of disgust. Although these studies did not examine the regulation of the subjective experience or expression of disgust, they did find novel evidence for a central role of executive functioning in regulating the influence of disgust on moral judgments. (For similar evidence on the role of executive functioning in regulating the effect of alcohol on aggressive responding, see Giancola, 2004).

Summary

The research reviewed in this section demonstrates that individual differences in executive functioning predict success at emotion regulation. This relationship has been observed across diverse measures of executive functioning and diverse measures of emotion regulation. It holds across a range of ages and cognitive ability levels and has been detected both inside and outside of the laboratory. The most reliable predictor has been working memory capacity—an index of the executive function of updating. Performance on tests of working memory capacity has been associated with success at expressive suppression, cognitive reappraisal, self-enhancement in response to negative feedback, and coping with daily stressors. However, a couple studies found no relationship between working memory capacity and emotion regulation as assessed by startle responses to noise blasts.

The evidence is still relatively scarce pertaining to shifting and inhibition. One study found that shifting (as well as updating) predicted success at reappraisal, though other studies found null effects or failed to include a measure of shifting. Regarding inhibition, performance on the Stroop task has been found to moderate the expression of socially-inappropriate emotions and the effect of disgust on moral judgments, respectively, and another study found that performance on a stop signal task predicted more successful reappraisal of negative emotional stimuli. But a handful of other studies found null effects of inhibition or failed to include a standard behavioral measure of inhibition. This is surprising insofar as inhibition seems like an obvious candidate to play a role in emotion regulation. Two other studies found a reliable relationship between verbal ability and emotion regulation, though most of the studies we have reviewed did not include measures of verbal ability, and those that did found no significant relationship.

Altogether, the most appropriate conclusion is that cognitive ability is associated with success at emotion regulation, but the strength of the relationship depends on the specific executive functioning ability and the specific form of emotion regulation at issue. The trend has been for different investigators to use different measures of executive functioning and emotion regulation. One upshot of this trend is confidence in the existence of the relationship between the two constructs when the different methods yield converging evidence, and there are obvious signs of this in the research reviewed above. But different patterns of results across studies using different measures of the same constructs conspire to limit the conclusions that can be drawn. A great deal of theoretical and empirical work remains to be done to draw more specific conclusions about when and why executive functioning ability is associated with emotion regulation.

Experimental Evidence that Executive Functions Increase Success at Emotion Regulation

As we have seen, individual differences in executive functioning are associated with success at emotion regulation in both children and adults. This evidence supports the hypothesis that cognitive ability is an important key to emotion regulation, but the evidence reviewed so far suffers an obvious shortcoming: It does not establish a causal effect of executive functioning on emotion regulation. It is thus possible that the causal arrow flows in the opposite direction, such that poorer emotion regulation causes a deficit in executive functioning, not the other way around as we have assumed. It may also be that some other variable that we have not considered helps to explain the observed relationship between executive functioning and emotion regulation.

Compared to the growing stream of evidence based on individual differences in cognitive ability, the evidence from experiments examining the causal relationship between cognitive ability and emotion regulation is sparse. This is likely due in part to the inherent difficulty of manipulating cognitive ability, although we can think of two common experimental methods that could be used for this purpose. One is cognitive load. Occupying attentional resources with a cognitive load leaves fewer resources available for other tasks, and cognitive load is particularly harmful to tasks that rely on relatively more complex or controlled cognitive abilities. If executive functioning drives success at emotion regulation, then cognitive load—which temporarily disrupts executive functioning—should also undermine emotion regulation. The other is ego depletion, which refers to a temporary reduction in the capacity for self-control due to prior self-regulatory exertions. Some theorists have suggested that prior self-regulatory exertions temporarily reduce the capacity for executive functioning (see Inzlicht & Schmeichel, 2012). In this view, evidence that ego depletion undermines success at emotion regulation would suggest that executive functioning plays a causal role in emotion regulation. Below we review experiments that have manipulated cognitive load or ego depletion and assessed the consequences for emotional responding and emotion regulation.

Starting first with cognitive load, an experiment by Wegner, Erber, and Zanakos (1993) asked participants to recall a sad autobiographical memory and write it down. Some participants were instructed to not let themselves feel sad while they were writing, whereas others were encouraged to relive the sadness. The two groups reported different levels of happy mood at the end of the task, consistent with effective emotion regulation. Further, some participants attempted the above tasks under cognitive load (i.e., remembering a 9-digit number), and the results revealed that cognitive load undermines success at emotion regulation. In fact, participants who tried not to feel sad under cognitive load ironically experienced less happy mood compared to participants who relived their sadness. In addition to providing novel support for ironic process theory (Wegner, 1994), these findings were among the first to find that cognitive resources play a causal role in successful emotion regulation. When cognitive resources were diverted to another task, emotion regulation suffered.

To our initial surprise, we found no other experiments that have asked participants to regulate their responses to emotional stimuli in the presence versus absence of a concurrent cognitive load. The explanation for this is perhaps a simple one. The vast majority of studies on emotion regulation, unlike the early study by Wegner et al. (1993), have studied emotion regulation by having participants view emotional images and films. Cognitive load should distract attention away from the processing of such stimuli, and thus may be expected to reduce emotional responding even without the participant attempting to regulate their responses.

Consistent with this reasoning, several experiments have found evidence that cognitive load reduces emotional experience. For example, a series of studies by Van Dillen and Koole (2007) found that performing tasks that occupy working memory reduces the impact of negative emotional stimuli. In a first study, participants completed several trials of a task that involved viewing pictures, attempting math problems (or not), and then reporting their emotional state. The pictures depicted neutral, mildly negative, or strongly negative emotional content. Not surprisingly, participants reported more negative emotional states after viewing the negative pictures. More interesting was evidence that participants reported less negative emotional states when they solved math problems after viewing the negative images. In follow-up studies, Van

Dillen and Koole found conceptually similar evidence using different forms of cognitive load. Thus, the results consistently revealed that negative emotions could be down-regulated by tasks that occupy working memory.

A subsequent fMRI study by Van Dillen, Heslenfeld, and Koole (2009) replicated the finding that cognitive load reduces subjective responding to negative emotion stimuli and also found informative patterns of brain activation. Specifically, solving difficult math problems following negative pictures was associated with less activation in the amygdala and right insula, and more activation in the right dorsolateral frontal cortex, right superior parietal cortex, and left dorsal occipital cortex, respectively. One way to think of these patterns is that the engaging the executive control centers of the brain reduced activation levels in emotional centers of the brain. Thus, similar to the evidence from fMRI studies of cognitive reappraisal cited earlier in this chapter, the results from experiments using cognitive load suggest that frontal cognitive functioning is a crucial determinant of subjective and physiological responses to emotional stimuli.

Another way to examine the role of cognitive resources in emotion regulation is to manipulate the presence versus absence of emotion regulation attempts and assess the effects on concurrent task performance. A study by Ortner, Zelazo, and Anderson (in press) adopted this approach by asking participants to view neutral and unpleasant images while performing a concurrent auditory discrimination task. Further, participants were instructed to suppress or to reappraise their responses to some of the images and simply to view the others. Consistent with the hypothesis that emotion regulation can be an effortful, attention-demanding endeavor, responses to the auditory discrimination task were slower when participants attempted emotion regulation (suppression or reappraisal) versus no emotion regulation during picture viewing.

Thus, attempting emotion regulation diverted cognitive resources away from a concurrent task.

Studies of ego depletion also support the view that emotion regulation relies on limited resources. For example, participants in one study solved moderately difficult multiplication problems or listed their thoughts while trying to avoid thinking of a white bear (Muraven, Tice, & Baumeister, 2008, Study 3). Then all participants watched a humorous film clip under instructions to stifle their emotional responses. Based on the idea that suppressing a forbidden thought would temporarily deplete limited resources for self-control whereas solving math problems would not, Muraven and colleagues predicted that participants in the thought suppression condition would exhibit more mirthful responses to the film clip compared to participants in the math condition. The videotaped records of participants' faces during the humorous film clip supported this prediction (see also Schmeichel, 2007, Study 3). Participants were less successful at suppressing their emotional expressions after inhibiting a forbidden thought, relative to attempting math problems. An experiment by Schmeichel (2007, Study 3) provided a conceptual replication of this finding. Insofar as prior self-regulatory exertion temporarily reduces the capacity for executive functioning, these findings support the view that executive functions are causal determinants of success at emotion regulation.

Summary

Experiments that have temporarily depleted or imposed a load on cognitive resources have yielded evidence supporting the hypothesis that executive functioning plays a causal role in successful emotion regulation. But this evidence suffers from shortcomings that prevent definitive conclusions. First, only one study has manipulated cognitive load and examined its effects on purposeful efforts to regulate emotion. More such studies are needed, but they will have to contend with the fact that cognitive load reduces emotional responding directly, independent of any efforts at emotion regulation. That is, regardless of whether a person is trying to regulate their emotions, performing a cognitive task while attending to emotional stimuli reduces activation levels in emotional centers of the brain and reduces subjective emotional experience. Thus, an experiment that includes orthogonal manipulations of cognitive load and emotion regulation (e.g., reappraisal) would be expected to observe reduced emotion due both to the emotion regulation attempt and to the cognitive load (cf. Kamphuis & Telch, 2000). Such results would confirm that cognitive load is itself an effective tool for emotion regulation but would tell us very little about the extent to which cognitive load disrupts emotion regulation.

The results from ego depletion experiments are perhaps more informative, but these too suffer from interpretational ambiguities. Although evidence suggests that prior self-regulatory exertion temporarily reduces the capacity for executive functioning (e.g., Schmeichel, 2007; Clarkson, Hirt, Chapman, & Jia, 2011), it has not been established that reduced executive functioning mediates the effects of ego depletion on emotion regulation. Furthermore, evidence has begun to suggest that prior self-regulatory exertions may increase the strength of emotional and motivational urges (Inzlicht & Schmeichel, 2012; Vohs et al., 2013). Thus, reduced success at emotion regulation under ego depletion may reveal stronger emotional impulses, rather than or in addition to reduced capacity for executive control (see Schmeichel, Harmon-Jones, & Harmon-Jones, 2010). Until a more detailed process model of ego depletion has been established, definitive conclusions about the role of executive functions in ego depletion effects must be put on hold. More generally, until an ethically acceptable and more process pure method of reducing cognitive ability is established, causal evidence for the role of the executive functions in emotion regulation will remain elusive.

Conclusion

The evidence reviewed in this chapter supports the conclusion that executive functioning is an important key to success at emotion regulation. Although more research is needed to understand the inconsistent results observed across some of the studies and to find more evidence for a causal relationship, we believe such research would be greatly enhanced by the development of comprehensive theories and the identification of candidate mechanisms to link the two constructs. We hasten to note that, in addition to the evidence reviewed in this chapter, research from developmental psychology and cognitive and affective neuroscience corresponds with the evidence reviewed here and may provide important clues for how to proceed. For instance, one promising approach may be to identify brain structures that underlie both specific executive functions and specific forms of emotion regulation (e.g., Tabibnia et al., 2011). The presumption is that if two different types of tasks recruit the same brain structures, they rely on similar processes.

Of course, although the evidence reviewed here reveals links between executive functioning and emotion regulation, the two constructs are far from isomorphic. Emotional and non-emotional information may be processed differently and in different parts of the brain (e.g., Soutschek & Schubert, 2013). Nonetheless, research indicates that executive functioning and emotion regulation overlap and share at least some common physical and psychological basis.

One unanswered question concerns the relative contributions of executive functioning versus other individual differences that have been found to predict success at emotion regulation. As noted at the outset of this chapter, self-esteem, conscientiousness, agreeableness, and asymmetric activation of the frontal cortex have all been found to predict success at emotion regulation. How do individual differences in executive functioning relate to these variables, and does executive functioning contribute predictive power above and beyond these other traits? We presume that it does, but evidence on this point is lacking. It may be the case, for example, that persons higher in executive functioning are also more conscientious, and that the two variables account for redundant variance in emotion regulation outcomes.

It is interesting to us that nearly a century of research on individual differences in cognitive ability has dutifully documented its role in a wide variety of outcomes including academic achievement, job performance, physical health, and socioeconomic status, among several other outcomes (for a recent overview, see Nisbett et al., 2012), but very little research has examined potential relationships between cognitive ability and emotions. A recent study on a nationally-representative of Britons found a strong positive relationship between cognitive ability and happiness (Alia et al., 2012), and another found a positive relationship between cognitive ability and positive affect in a sample of over 500 older adults (Isaacowitz & Smith, 2003). We are optimistic that such evidence will spur more research into understanding why people with more cognitive ability are happier. In addition to other known correlates of cognitive ability, such as professional achievement and physical health, we believe success at emotion regulation is likely to be another key contributor. We hope the next century of research on cognitive ability pays closer attention to emotional processes and responses, and how and why cognitive ability shapes them.

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Table 1

Summary of studies assessing individual differences in executive functioning and emotion regulation.

Article	Sample	Measure of Executive Functioning	Measure of Emotion Regulation
Kochanska, Murray, & Harlan (2000)	106 children at 22 and 33 months of age	Battery of 11 effortful control tasks	Emotional expressiveness in response to humorous puppets and physical restraint
Kieras, Tobin, Graziano, & Rothbart, 2005	62 children between 3 and 5 years of age	Battery of 7 effortful control tasks	Emotional expressiveness in response to receiving less (versus more) desirable gift
von Hippel & Gonsalkorale (2005)	71 undergraduates	Stroop task (inhibition)	Negativity of emotional expression in response to invitation to eat a chicken foot
Schmeichel, Volokhov, & Demaree, 2008	Study 1: 45 undergraduates Study 2: 50 undergraduates Study 3: 71 undergraduates Study 4: 63 undergraduates	Study 1: OSPAN (updating) Study 2: OSPAN Study 3: spatial and verbal 2-back tasks (updating) Study 4: OSPAN	Study 1: Expressive suppression during disgusting film Study 2: Expressive suppression during humorous film Study 3: Reappraisal of disgusting film Study 4: Reappraisal of sad or humorous film
Gyurak et al., 2009	48 adults, including 31 with neurodegenerative disease	Digit span, spatial span, Stroop task, trail making test, verbal fluency tasks	Facial expressiveness and body movement in response to anticipated and unanticipated noise blasts
Schmeichel & Demaree, 2010	102 undergraduates	OSPAN	Self-enhancement in response to negative feedback

Stawski, Almeida, Lachman, Tun, & Rosnick, 2010	1,202 adults ranging from 40-59 years of age	Episodic verbal memory test, WM span, category fluency, inductive reasoning, processing speed	Daily reports of emotional response to stressors
Tabibnia et al., 2011	44 healthy adults and 43 meth-dependent adults	Stop-signal task	Reappraisal of negative emotional images
Gyurak, Goodkind, Kramer, Miller, & Levenson, 2012	69 adults, including 48 with neurodegenerative disease	Digit span, spatial span, Stroop task, trail making test, verbal fluency tasks	Heart rate and facial expressiveness when hiding expressions, amplifying expressions, or simply watching disgusting films
McRae, Jacobs, Ray, John, & Gross, 2012	89 healthy adults	OSPAN, global/local task (shifting), verbal ability, Stroop task, abstract reasoning	Reappraisal of negative emotional images
Van Dillen, van Wal, & van der Bos (2012)	74 undergraduates (Study 1)	Stroop task	Impact of disgust on moral judgments