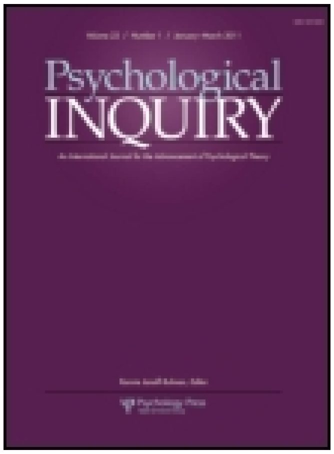

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Variation in Cognitive Control as Emotion Regulation

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Few fields in psychological science are growing as quickly as emotion regulation. Undoubtedly hastened by the introduction of the process model of emotion regulation (Gross, 1998), researchers have identified a broad array of emotion regulatory tactics, each serving to alter the intensity, duration, or quality of the unfolding emotional response. In addition to being a buoyant research area in its own right, concepts from emotion regulation have permeated multiple subdisciplines of psychology, including biological, cognitive, clinical, developmental, personality, and social approaches, to name a few. Given this rapid expansion, the time is ripe not only to take stock of recent advancements but also to formulate new ideas about the mechanisms that govern emotion regulation. In this light, we welcome the synthesis and conceptual development provided by the extended process model of emotion regulation (Gross, this issue). However, we also believe that the targets of emotion regulation might range further than is typically acknowledged by existing models. Here, extending contemporary accounts of emotion regulation, we explore the idea that the implementation of cognitive control—one other emergent feature of the mind—can also be viewed as a form of emotion regulation, initiated to reduce the unpleasant experience of challenges to goal-directed behavior.

In broad terms, cognitive control underlies intentional action, calibrating attentional, cognitive, and action systems to better attain performance goals, particularly in novel or challenging situations (Banich, 2009). Control is distinguished from automatic processing, where responses are implemented in a habitual and spontaneous manner. Of importance, rather than reflecting the execution of a unitary psychological process, cybernetic approaches decompose control into (at least) three core subsystems, including goal setting, control implementation, and monitoring (Carver & Sheier, 1990; Inzlicht, Legault, & Teper, 2014). First, *goal setting* represents current performance intentions (e.g., name ink color, eat healthily), and *implementation* systems calibrate ongoing information processing toward the fulfillment of these goals. Crucially, a continual *monitoring* process detects events that conflict with current objectives (e.g., errors or unwanted impulses), providing feedback to the implementation systems about the fluctuating need to increase or relax levels of control (Botvinick et al., 2001; Carver & Scheier, 1990).

Several existing models have identified ways in which controlled processes can regulate automatic emotional impulses (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Ochsner & Gross, 2005; Teper, Segal, & Inzlicht, 2013). Here, rather than further specifying how control processes might serve the regulation of prototypical affective material (e.g., negative imagery, distressing life events), we consider how the process of regulating emotional experiences might apply to the calibration of cognitive control, even for tasks that are not explicitly emotional in nature. In this regard, we suggest that emotional processing is inherently involved in goal-directed behavior. For example, in addition to coldly representing the requirements of the task at hand, our performance goals represent the value of successful performance; goal attainment is particularly valuable when goals align with overarching values and beliefs (Deci & Ryan, 1985), are externally incentivized (Chiew & Braver, 2011), or when a represented objective is personally meaningful (Proulx, Inzlicht & Harmon-Jones, 2012). Consequently, we suggest that situations requiring the use of control (e.g., conflict, errors, temptations) are particularly salient when goals are valued, triggering a transient negative affective state that (a) can be characterized as a type of emotion episode and (b) initiates regulatory action (Inzlicht & Legault, 2014; Saunders & Inzlicht, in press).

In this commentary, rather than directly critiquing the extended process model (Gross, this issue), we note the generative nature of this model for understanding established cognitive control phenomena. First, we present evidence that situations requiring control trigger a negative emotional episode and then discuss two strategies (increasing control and shifting priorities) that can be implemented to regulate this emotion. Finally, we articulate our view within a broader, hierarchically organized, valuation process that directs variation in control to achieve "cognitive comfort".

Control-Demanding Situations Trigger an Emotional Episode

As described by Gross (this issue), emotions have a multimodal structure: Emotional episodes begin with a *situation* or *antecedent event* that triggers an affective evaluation (positive vs. .negative), as well as "loosely coupled" activation across several affective response systems, including cognitive processing (e.g., attribution, appraisal), autonomic arousal (e.g., heart rate deceleration, pupil dilation, sweating), facial expressions (e.g., frowning, smiling), behavior (e.g., running, fighting, dancing), subjective feelings (feeling anxious, happy, fearful), and characteristic patterns of neural activation (Coan, 2010; Russell, 2003). Consistent with this definition, considerable evidence now suggests that situations requiring control (e.g., conflict and errors) trigger an emotional episode.

First, there is ample evidence that situations demanding cognitive control involve the basic "*good for me*" versus "*bad for me*" valence judgments that are central to emotional experience. For example, modified affective priming studies reveal that "conflict" primes (e.g., incongruent Stroop stimuli; Dreisbach & Fischer, 2012) and response errors (Aarts, De Houwer, & Pourtois, 2012) facilitate and interfere with the identification of subsequently presented negative and positive targets, respectively. Further indicating that control challenges are negatively valenced (Larsen, Norris, & Cacioppo, 2003), both conflict and errors provoke the contraction of the frowning musculature of the face (*corrugator supercilii*; Lindström, Mattsson-Mårn, Golkar, & Olsson, 2013). Beside mere negative valence, control challenges elicit arousal of the autonomic nervous system (Danev & Winter, 1971; O'Connell et al., 2007; van Steenbergen & Band, 2013) and subjective emotional experiences of distress (Bartholow, Henry, Lust, Saults, & Wood, 2012), anxiety (Inzlicht & Al-Khindi, 2012; Proudfit, Inzlicht, & Mennin, 2013), frustration (Spunt, Lieberman, Cohen, & Eisenberger, 2012), and decreased momentary happiness (Milyavskaya & Koestner, 2014). Finally, the neural correlates of performance monitoring appears to track not only the fluctuating need for control but also the affective valence of ongoing events (Koban & Pourtois, 2014; Shackman et al., 2011). Indicating the rapidity of these evaluations, the error-related negativity (ERN)—an event-related potential that peaks within 100 ms of error responses (Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; Gehring, Gross, Coles, Meyer, & Donchin, 1993)—varies systematically with events that increase or decrease the affective significance of mistakes (Proudfit et al., 2013). Thus, collectively, these findings from diverse research disciplines converge to suggest that control-demanding situations trigger an emotional episode, characterized by negative valence, increased arousal, and the engagement of multiple affective response systems.

Variation in Cognitive Control as Emotion-Regulation

In the previous section, we articulated our view that situations requiring cognitive or self-control trigger an emotion episode. Next, we consider what adaptive purpose—if any—these task-related emotions serve. When defining the targets of emotion regulation, Gross (this issue) distinguishes between "helpful" and "harmful" emotions. Harmful emotions—crippling despair, social anxiety, violent anger—bear undesirable outcomes for the individual (e.g., self-harm, social exclusion), and, therefore, are candidate targets for emotion regulation. On the other hand, helpful emotions—the joy of friendship, disgust for sources of contagion, pretest anxiety—drive actions with beneficial outcomes, and are therefore considered more welcome forms of affective experience. In our view, however, a strong distinction between "helpful" and "harmful" might represent a false dichotomy when identifying the targets of emotion regulation. Instead, emotions might be considered "helpful" in the extent to which they motivate seemingly adaptive behaviors to regulate exposure to "harmful" events. Feeling anxious before an important exam, for example, might motivate more focused revision sessions (a helpful behavior) to prevent failure in a valued academic domain (a harmful outcome). Similarly, in the context of cognitive control we suggest that the implementation of actions in response to control-demanding situations *is* a form of emotion regulation, implemented to reduce the unpleasant experience of goal conflict on future performance (see Gyurak, Gross, & Etkin, 2011, for a similar suggestion).

Overall, we have recently suggested that people regulate control levels in a homeostatic manner, aiming to achieve "cognitive comfort"—a subjectively pleasant state free of the aversive experience of goal conflict (Saunders & Inzlicht, in press). To best achieve this goal, we suspect that individuals pursue valued, rewarding, or gratifying outcomes while avoiding events that threaten goal attainment or provide a potential source of punishment. Consequently, in our view, variation in cognitive control is closely tied to the fluctuating affective experiences that arise during task performance. At its core, this view is consistent with the basic premise of most theories of emotion, suggesting that organisms aim to achieve safety, pleasure, and reward while minimizing discomfort, punishment, and harm (Frijda, 1988; Panksepp, 2008; Russell, 2003). This view is also consistent with emerging models of control, which propose individuals are driven to avoid the "inherent disutility" of conflict and cognitive demands (Botvinick, 2007). Consequently, the unpleasant experience triggered by situations requiring control might make goal-threatening events salient (Frijda, 1988), and, in turn, influence the regulation of control (Inzlicht & Legault, 2014).

Rather than reviewing evidence for the influence of affective processing on cognitive control (for recent reviews, see Cavanagh & Shackman, 2014; Chiew & Braver, 2011; Proudfit et al., 2013; Shackman et al., 2011), we consider how variation in cognitive control varies systematically across established strategies of emotion regulation, focusing on two strategies that can be especially useful in regulating the affective sting of conflict. First, people might directly increase control within the current task to reduce the influence of conflict and the accompanying negative affect. Alternatively, a second option is to relinquish control in pursuit of the currently represented goal and, instead, engage in more leisurely pursuits that provide an immediate source of gratification, potentially eschewing conflict-eliciting situations altogether. In line with the extended process model (Gross, this issue), we then focus on the dynamic valuation processes that might lead individuals to choose between these strategies over time, facilitating the overarching goal of achieving cognitive comfort.

Control and the Established Strategies of Emotion Regulation

Among the strategies for regulating emotional experience identified by the process model of emotion regulation (Gross, 1998), *cognitive change*—altering appraisals of the present situation to alter the unfolding emotional response —has been most widely studied in relation to cognitive control. Often exemplified by cognitive reappraisal, these *antecedent-focused* forms of emotion-regulation can either reduce or increase the intensity of emotions (Gross, 1998).

In a recent study (Hobson, Saunders, Al-Khindi & Inzlicht, in press), we wondered if such reappraisals modulate cognitive control. To this end, we had participants perform a canonical test of inhibitory control (go/no-go task) under three regulation instructions: down-regulate task emotions, up-regulate task emotions, and perform as normal (control condition). Of interest, neural reactivity to errors (ERN minus correct-trial ERP difference) was selectively attenuated under emotion down-regulation instructions, relative to up-regulation and control conditions. Further indicating the affective nature of this attenuation, the effects of regulation condition on performance monitoring were mediated by changes in subjective emotional experience rather than subjective *involvement*. Pertinent for current concerns, however, was the finding that the effect of down-regulation on the ERN indirectly predicted reduced inhibitory control performance (no-go false alarm rate). We suggest that these patterns of results occur because down-regulation instructions reduce the negative affective sting of errors, meaning that participants no longer feel the need to increase control levels in order to soothe the affective pang of their mistakes.

During emotional episodes, individuals also attribute—or misattribute—the cause of their emotional experience to a specific source event (Schacter & Singer, 1962). In one further study, Inzlicht and Al-Khindi (2012) wondered if control-related affect was also susceptable to attibution as a further cognitive moderator of emotion. In this study, neural error monitoring (ERN amplitude) was attenuated when participants misattributed task-related arousal to the apparently anxiogenic effects of a sham herbal suplement, relative to participants in a nonmisattribution control condition. Further suggesting that this affective component of performance monitoring acutally contributes to the implementation of control, the ERN was predictive only of inhibitory control performance for participants in the nonmisattribution condition. A recent (unpublished) reanalysis of this data also revealed that the effect of misattribution on the ERN indirectly predicted variation in inhibitory control. Crucially, these findings indicate that up-regulating cognitive control may be selected only as an emotion regulation strategy if self-control failure is correctly identified as the source of the currently experienced negative affect.

Further evidence for the close coupling between cognitive control and affective processing has been provided by studying the shared influence of alcohol comsumption on both emotional processes and intentional action (Bartholow et al., 2012). It has previously been established that alcohol impairs both neural error monitoring and attentional control on trials immediately following errors (Ridderinkhof et al., 2002). In a recent study, however, Bartholow et al. (2012) reported that the ability of alcohol consumption to reduce both performance monitoring (ERN amplitude) and adaptive posterror adjustments was fully mediated by alcohol's anxiolytic effects on reported levels of negative affect. Again, these results are consistent with the idea that variation in cogntive control levels is driven by a need to regulate the unpleasant experience of performance failure, a need for regulation that is reduced when the negative experience of a control-demanding situation is reduced by other means.

Shifting Priorities and Control Avoidance

Thus far, we have suggested that control-related emotion might be best regulated by increasing control levels within in the current task context (e.g., conflict control, error adaptation). In this regard, task-related negative affect may be considered "helpful" (cf. Gross, this issue) as it promotes successful performance of the task at hand. The up-regulation of control, however, is but one regulatory tactic open to the individual to soothe the negative experience of conflict. If people are motivated to avoid unpleasant experiences, punishment, or harm, control-related emotions might more easily be escaped by disengaging from a demanding but un-rewarding task altogether and, instead, engaging with more gratifying activities to restore "cognitive comfort".

Highly relevant to this idea is the process model, or *shifting priorities model* of self-control (Inzlicht, Schmeichel, & Macrae 2014), which suggests that, over time, individuals devalue the performance of unrewarding, externally mandated "have-to tasks" and instead show an increased appetite for activities that they perceive to be more gratifying for "want-to" tasks (Inzlicht, Schmeichel, et al., 2014). Although the devaluation of externally dictated goals can explain why individuals perform poorly on sequential tests of control (Inzlicht, Berkman, & Elkins-Brown, in press)—commonly regarded as a "bad" outcome in the context of self-regulation (Baumeister, Vohs, & Tice, 2007)—such changes in motivational orientation might appear more adaptive when control is considered as a form of emotion regulation (Saunders & Inzlicht, in press).

Specifically, existing research suggests that protracted periods of cognitive labor foster a state of mental fatigue (Boksem & Tops, 2008; Inzlicht, Schmeichel et al., 2014), and, although certainly less tense than states of anxiety or frustration, fatigue is a fundamentally negative emotional experience (Russell & Barrett, 1999) that, in our view, triggers the goal to restore "cognitive comfort." Here, rather than driving the up-regulation of control in the specific, currently mandated task (e.g., "increase inhibitory strength"), mental fatigue might lead individuals to approach their environment in a more global, exploratory (cf. Cohen, McClure, & Yu, 2007; Kurzban, Duckworth, Kable, & Myers, 2013) manner, restoring cognitive comfort by looking to alternative activities for gratification.

Supporting this idea, briefly engaging in an enjoyable pursuit—such as watching television (Derrick, 2012), receiving a surprise gift (Tice, Baumeister, Shmueli, & Muraven, 2007) or smoking (Heckman, Ditre, & Brandon, 2012)—after performing an initial demanding task leads to improved self-regulation on a secondary control task. Of importance, despite each of these restorative activities not requiring self-control, we suspect that simply ending the performance of a demanding task is not sufficient to regain cognitive comfort after becoming fatigued. Instead, we suggest that finding some form of rewarding pursuit is required to maintain homeostasis. Although this gratification may often take the form of activities that require little self-control, like browsing social-media or daydreaming, pleasure can also arise from apparently challenging tasks, such as playing chess, music, or sport. Despite relatively few experimental paradigms offering participants the flexibility to choose between more and less gratifying tasks in laboratory settings, we believe that such changes in motivational orientation might be a highly prevalent method of emotion regulation in everyday life; the need to pursue a gratifying activity (e.g., socializing, watching a movie, playing a puzzle game) might be felt most keenly after engaging in unrewarding, unpleasant labor (e.g., building flat-pack furniture, administrative work, organizing data).

Comfort Seeking as a "Higher Order" Determinant of Control

If multiple strategies are available to regulate control-related emotion—either increasing control within the present task or disengaging from one task and pursuing more rewarding goals—it is important to understand why one specific regulation tactic is selected over another at any given point in time. Gross (this issue) identifies a similar challenge in the broader domain of emotion regulation, where individuals must "know" which strategy (e.g., cognitive reappraisal, expressive suppression, and attentional deployment) should be used to regulate a given emotional episode. According to Gross, dynamic interactions between distinct valuation systems can account for this problem. Specifically, emotional episodes arise out of evaluations ("is this situation good or bad for me"), which are in turn perceived by a higher level valuation system that detects unwanted states and, over time, selects between emotion regulation tactics that can bring lower level emotional experiences in line with the desired state. Of importance, we believe that similar hierarchical valuation processes can explain why individuals might decide between responding to control-demanding situations with increased control (vigor) or by disengaging from the control-demanding situation altogether and exploring other options (fatigue; see Saunders & Inzlicht, in press).

Generally, hierarchically organized control systems propose that superordinate goals (i.e., abstract intentions that are relatively fundamental to our self-concept) have the ability to influence the operation of ever lower level, increasingly domain-specific control systems (i.e., the systems that directly implement programs for a particular intentional action; Carver & Scheier, 1990). Here, we suggest that the higher order system detects for discrepancies between current events and the need for "cognitive comfort" while the lower level system represents more specific task goals, and the types of implementation strategies that might best achieve these goals (e.g., resist prepotent impulses). In line with other models of hierarchically organized behavior (Carver & Scheier, 1990), we suggest that failure to exert sufficient control on the immediate task not only registers as a conflict between outcomes and lower level intentions but also is discrepant with the broader goal to achieve cognitive comfort. When playing a musical piece, for example, hitting the wrong key not only conflicts with the immediate goal to play the correct note but also triggers discomfort if it challenges broader goals to be a good musician or impress an audience. In such situations, comfort might be restored through two actions, either increasing the value of successful performance, leading to renewed focus on the profitable task at hand, or, particularly if the individual does not value success on the current task, disengaging from the cause of discomfort and seeking out new sources of gratification.

Processing Dynamics

The processing dynamics of our viewpoint build on existing cognitive architecture, as defined by prior research. First, the computational basis of the lower order, tasks-specific system might be based on conflict detection (Botvinick et al., 2001), where outcomes are compared to represented task goals, signaling for increased control when goal conflict is detected. To account for recent findings from affective neuroscience, however, we suggest that this process also comprises an affective component, determining the valence of control demanding events and triggering a multimodal response that is consistent with contemporary definitions of an emotional episode. Of importance, by making the control demanding situation salient, we suggest that the unpleasant experience of conflict drives individuals to exert greater control on the current task as a form of emotion regulation. Conversely, this affective alarm signal is less effective when factors moderate the "affective sting" of conflict (Bartholow et al., 2012; Hobson et al., in press; Inzlicht & Al-Khindi, 2012). Thus, although we do not suggest that affective responses to control-demanding situations can replace conflict monitoring, we propose that these emotional responses play an integral role in driving the up-regulation of control (Inzlicht & Legault, 2014).

Of importance, however, our hierarchical model also suggests that the strength with which this "affect alarm" responds to goal conflict is modulated by the broader, second-level goal to achieve cognitive comfort. More specifically, we suggest that the discrepancy between task failure and the higher order goal to achieve cognitive comfort is greatest when a goal is highly valued (due to either intrinsic or extrinsic motivational factors). Upon experiencing this discomfort, the second-level system further strengthens the value of the lower level task goal, resulting in higher levels of control implementation *and* greater affective responses to conflict if failure reoccurs in this increasingly valued domain. Indeed, potentiated neuroaffective reactivity to errors and energized cognitive control efforts are observed when successful task performance is made more valuable through self-determination (Legault & Inzlicht, 2013) or when performance is paired with external reward–punishment contingencies (Riesel, Weinberg, Endrass, Kathmann, & Hajcak, 2012; Stürmer, Nigbur, Schacht, & Sommer, 2011). In these situations, task disengagement is an unlikely source of comfort, as reducing control levels within the current task would risk further exposure to these unwelcome events.

In most laboratory experiments, however, participants perform relatively mundane cognitive control tasks without performance contingent rewards, punishments, or the presence of other moderators of emotion. In such circumstances, although participants might initially see some value in accurate performance—perhaps to oblige the experimenter or out of self-determined effort—we suspect that the cumulative experience of repeated cognitive discomfort, not counteracted by extrinsic or intrinsic motivation, promotes a qualitatively different affective state, characterized by mental fatigue (Boksem & Tops, 2008; Inzlicht, Schmeichel, et al., 2014). Here, because task performance is not perceived as particularly rewarding, we suggest that errors fail to elicit cognitive discomfort, resulting in the steady devaluation of the proximal goal, diminishing the desire and effort used to recruit cognitive control. Supporting this idea, reduced neuroaffective reactions to errors and less effective behavioral performance is observed when participants perform a second control task after initial bouts of cognitive control (Inzlicht & Gutsell, 2007; Wang, Yang, & Wang, 2014) or when they perform a single unrewarded task for a protracted period (>2 hr; Boksem, Meijman, & Lorist, 2006).

Yet mental fatigue is still a negative affective state (Russell & Barrett, 1999), a state that is discrepant with the overarching goal to achieve cognitive comfort. Of importance, the termination of an unrewarding task alone is likely unable to restore cognitive comfort. Instead, fatigue states might be regulated by engaging with sources of reward or gratification if such activities are available in the immediate environment (Schmeichel, Harmon-Jones, & Harmon-Jones, 2010). In this regard, the higher order value to maintain cognitive comfort might increase the subjective value of engaging with subjectively gratifying pursuits—including both low- and high-demand activities—thereby driving the motivational switching that might underlie a great deal of variation in the effectiveness of self-control (Baumeister et al., 2007; Inzlicht, Schmeichel et al., 2014) Crucially, we suggest that comfort is achieved by engaging with gratifying tasks, rather than by seeking novel pursuits per se. For example, introducing performance contingent rewards—a source of cognitive comfort—to an inherently unrewarding task that was initially the source of fatigue can reinvigorate both performance monitoring and the implementation of control (cf. Boksem et al., 2006).

Finally, as we have derived our hierarchical view of control primarily from laboratory studies, it is important to consider how emotional responses might play out in real-life self-control dilemmas. For example, a spontaneous offer of "free chocolate" may present itself as a goal conflict to someone who is trying to diet. On one hand, the "affective sting" caused by this unexpected conflict might lead the individual to inhibit this urge, and probably feel good about sticking to his or her diet. Conversely, if the person is in a fatigued state, perhaps after spending an entire day resisting dietary temptations, he or she may accept the chocolate as the gratification that can be obtained from its consumption temporarily outweighs the current subjective value of the dietary goal. But what are the consequences of this transgression for the individual's emotional state? Although such "comfort eating" might regulate the unpleasant experience of fatigue in the moment, feelings of guilt may arise later when people appraise this self-control failure in regard to their broader goals. Over time, we suspect that these guilty feelings might lead the individual to reevaluate their goals. Such reevaluation may result in perceiving the goal as more personally important, leading to better impulse control in future conflicts, or alternatively to disengagement from the goal altogether, and the setting of other goals.

Concluding Remarks

In the present commentary, we have outlined our view that dynamic variation in cognitive control can be viewed as a form of emotion regulation. First, we highlighted the now considerable evidence that challenges to successful goal-directed behavior result in a pattern of affective responses consistent with established definitions of an emotional episode. Subsequently, we presented our view, largely consistent with the extended process model, where the up- or down-regulation of control is used to soothe the affective sting of conflict in pursuit of an overarching goal to achieve a more subjectively pleasant state of "cognitive comfort." By casting variation in cognitive control in this affective light, we provide a more consilient view of self-regulatory actions, indicating that similar interacting valuation processes might underlie dynamic variation in both cognitive control and emotion regulation.

Note

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