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VIGOUR AND FATIGUE

How Variation in Affect Underlies Effective Self-Control

Blair Saunders and Michael Inzlicht

Self-control is implicated in the greatest triumphs and failures of the human condition (Baumeister, Vohs, & Tice, 2007). When control levels are high, we are able to resist impulses and rapidly correct our behaviour if we inadvertently succumb to temptation. When we lack self-control, behaviours become reflexive and automatic, initiated as a course of habit rather than deliberate exertion. But what factors determine variation in the effectiveness of self-control? Why do we respond to some temptations with renewed vigour in the pursuit of a current goal, while in other situations self-control appears exhausted, allowing impulses and (bad) habits to dominate performance? Here we explore the psychological factors that underlie fluctuations in control, articulating our view that affective processing drives variation in regulatory processes to a larger extent than acknowledged by other treatments of self-control.

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Self-Control as an Emotional Episode

Also labelled as executive functioning, cognitive control, or willpower, self-control encompasses a range of mental processes that allow us to flexibly adapt behaviour to better achieve our goals. Effective self-control depends upon the orchestrated activity of multiple partially independent processes, including goal maintenance, performance monitoring, and behavioural regulation (Banich, 2009; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Braver, 2012; Miyake et al., 2000). Laboratory studies of self-control employ several experimental protocols, including common conflict-control paradigms (e.g., flanker, Stroop, and go/no-go paradigms) and a range of other measures designed to operationalize physical or mental persistence (e.g., pain tolerance; hand-grip duration; puzzle perseverance). While abstracted from the challenges of everyday life, these experimental protocols

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predict adaptive outcomes in an impressive array of real-world situations, including academic attainment (Hirsh & Inzlicht, 2010), emotion regulation (Compton et al., 2008), and the restriction of racial prejudice (Payne, 2005).

In addition to coldly dictating behavioural intentions, however, performance goals incorporate the motivational significance of successful performance: The value of goal attainment is particularly high when goals are personally meaningful (Proulx & Inzlicht, 2012), are intrinsically motivating (Deci & Ryan, 1985; Legault & Inzlicht, 2013), or are incentivized with external rewards (Chiew & Braver, 2011). When such processes ascribe high value to successful performance, temptations, impulses, and overt actions that conflict with these goals are particularly salient. It is these *antecedent events* that, we suspect, induce transient changes in affect that can be viewed as a type of emotional episode.

In conceptualizing self-control in this affective light, we rely upon established criteria for defining an emotional episode (Russell, 2003, 2009; Russell & Barrett, 1999). First, *core affect* might be considered the epicentre of emotional episodes (Russell, 2003). Core affect comprises the unified, non-reflective experience of two independent dimensions—namely, valence (pleasure-displeasure) and arousal (activation-deactivation). While the present state of core affect is assumed to represent an omnipresent "background" feature of human experience, specific emotional episodes arise when an antecedent event causes a shift in valence and/or arousal, with the speed and magnitude of these changes bringing core affect into focus (Russell, 2003, 2009). When consciousness is brought to core affect, mental categorization processes identify a prototypical emotional episode (Barrett, 2006). High-activation negative states might produce feelings of *anxiety*, *fear*, or *tension*, while low-arousal negative affect can be experienced as *depression*, *tiredness*, or *fatigue*. Conversely, *elation* or *calmness* arises from the categorization of high- and low-arousal positive states, respectively. Emotional episodes also comprise changes in facial expressions (e.g., frowning or smiling) and autonomic arousal (e.g., heart rate, pupil dilation, skin conductance changes). Finally, multiple cognitive processes can moderate the emotional episode: Attribution processes identify (or misidentify) the source of the change in affect (Schacter & Singer, 1962), while appraisal processes might determine adaptive responses to this emotion (Gross, 1998; Russell, 2003).

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Errors and Conflicts Have a Negative Affective Tone

A number of recent studies have investigated the emotional sequelae of conflict across a number of cognitive and psychophysiological measures. These studies indicate that conflict coincides with observable negative affective arousal.

Conflict primes negative affect. Affective priming is a robust phenomenon where identifying the valence of a target is facilitated by prior primes with a congruent affective valence (Fazio, Sanbonmatsu, Powell, & Kardes, 1986). As such, categorization of the word "FOUL" will be faster if it is preceded by the negative prime "HATE" than the positive cue-word "HAPPY." Interestingly, modified versions of this affective

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priming paradigm have demonstrated that mental processes automatically assign negative valence to self-control challenges. Specifically, categorization time for negative and positive words is faster and slower, respectively, when these words are preceded by incongruent (vs. congruent) Stroop trials (Dreisbach & Fischer, 2012) or response errors (vs. correct actions) (Aarts, De Houwer, & Pourtios, 2012, 2013).

Conflict induces affective facial responses. Electromyographic (EMG) investigations of facial musculature provide a covert measure of affective processing. In human EMG experiments, contraction of the frowning musculature of the face (*corrugator supercilii*) co-occurs with negative affect (Larsen, Norris, & Cacioppo, 2003). Consistent with suggestions that control challenges are aversive, increased corrugator activity is observed within 100 ms of erroneous actions (Lindström, Mattson-Mårn, Golkar, & Olsson, 2013). Interestingly, this error-related corrugator engagement increased when errors were associated with punishment, further indicating that facial musculature tracks the affective significance of errors (Lindström et al., 2013).

Conflict arouses the peripheral nervous system. Emotional episodes are associated with arousal of the peripheral nervous system (Russell, 2003, 2009). Interestingly, strong evidence also links self-control failure with several metrics of autonomic arousal, including heart rate deceleration (Danev & De Winter, 1971; Hajcak, McDonald, & Simons, 2003), pupil dilation (Critchley, Tang, Glaser, Butterworth, & Dolan, 2005), and increased skin conductance responses (Hajcak et al., 2003; O'Connell et al., 2007), strongly suggesting that control challenges initiate autonomic arousal.

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The subjective experience of control. Less explicitly studied is the subjective phenomenology of self-control; however, a number of emotional terms have been used to label conflict experience, including distress (Bartholow, Henry, Lust, Saults, & Wood, 2012), anxiety (Cavanagh & Shackman, in press; Gray & McNaughton, 2000; Inzlicht & Al-Khindi, 2012), and frustration (Spunt, Lieberman, Cohen, & Eisenberger, 2012). Importantly, rather than highlighting a problematic inconsistency in the literature, we note that each of these prototypical emotions could arise from a similar state of core affect, characterized by negative affect and—we suspect—a low to moderate increase in arousal from normal baseline levels.

Summary. Together, evidence from studies of affective priming, facial EMG, psychophysiology, and subjective phenomenology converges on the viewpoint that goal conflict is experienced as a negative emotional episode. In the following, we consider how this negative affect might be integrated with neural performance monitoring systems.

Performance Monitoring

The past two decades have witnessed thriving research efforts to elucidate the neural substrates of self-control, postulating that distinct brain areas underlie various aspects of controlled performance (Banich, 2009; Botvinick et al., 2001; Ridderinkhof et al., 2004). Foremost, the anterior cingulate cortex (ACC) has been proposed as a neural hub of performance monitoring, assumed to evaluate the present need for control,

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and relay this signal to other brain areas capable of biasing ongoing information processing (Botvinick et al., 2001; Kerns et al., 2004; Ridderinkof et al., 2004).

Of particular interest to our research is the error-related negativity (ERN), an event-related potential (ERP) associated with performance monitoring (Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; Gehring, Goss, Coles, Meyer, & Donchin, 1993). The ERN reflects a negative deflection at frontocentral electrode sites that arises soon (0–80 ms) after error commission in the response-locked ERP. Consistent with its putative role in performance monitoring, the ERN has been localized to the ACC (Dehaene, Posner, & Tucker, 1994; Luu, Tucker, Derryberry, Reed, & Poulsen, 2003; van Veen & Carter, 2002).

Several cognitive models have provided differing accounts of the functional significance of the ERN. Common to most models, however, are suggestions that the ACC is sensitive to goal-incongruent events. In one computational model, for example, the ACC putatively detected levels of conflict between competing response representations, with increased control serving to reduce future conflicts (Botvinick et al., 2001). Another reinforcement learning account proposes that the ACC reacts to events that are "better" or "worse" than anticipated, subsequently increasing control to bring performance into line with expectations (Holroyd & Coles, 2002). Importantly, these computational accounts have often modelled monitoring phenomena without explicit reference to affective processing. However, as we will outline, significant research now indicates that neural monitoring processes evaluate the affective significance of ongoing events, proposing that affective processing should be integrated into current theories of self-control.

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Affective Processing, the ACC, and Performance Monitoring

The cingulate cortex has long been implicated in affective processing. In his seminal work on the neural circuitry of emotion, Papez (1937) associated the cingulate with a range of emotional states, including apathy, sadness, euphoria, and irritability. While modern neuroimaging initially compartmentalized the ACC into distinct affective-rostral and cognitive-dorsal subregions (Bush, Luu, & Posner, 2000), recent meta-analyses have co-localized seemingly heterogeneous mental processes, such as negative affect, fear conditioning, pain perception, reinforcement learning, and cognitive control, to overlapping portions of the dorsal ACC (Etkin, Egner, & Kalisch, 2011; Shakman et al., 2011). In parallel to these reports, researchers have also attempted to reconcile competing accounts of performance monitoring, postulating that the ACC serves cognitive control in a more general sense, evaluating aversive or costly events that challenge goal attainment (Botvinick, 2007; Proudfit, Inzlicht, & Mennin, 2013; Shenhav, Botvinick, & Cohen, 2013).

In the following sections we briefly articulate our view that performance monitoring largely reflects a negative affective response to control challenges. As evidence for this assertion, it is necessary to support three premises: (1) neural monitoring processes should covary with other measures of control-related affect;

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(2) neural reactivity to conflict should be increased when the affective significance of errors is high; and (3) performance monitoring should be attenuated by established modulators of affective experience.

Neural monitoring covaries with control-related affect. In their affective priming study, Aarts et al. (2013) demonstrated that ERN magnitude directly predicts the extent to which errors on a non-valenced go/no-go task facilitate the processing of subsequent negative words. Crucially, this finding demonstrates that very early (< 100 ms) neural monitoring processes evaluate the affective valence of actions. In a complementary study, Spunt et al. (2012) found that error-related activation of the dorsal ACC also tracks self-reported negative affect (frustration) during stop-signal task performance.

Neural monitoring is increased when affective value of performance is high. Considerable evidence indicates that neural monitoring increases with the affective or subjective value of accurate performance (i.e., integral affect; see Schmeichel & Inzlicht, 2013). Neural monitoring (ERN amplitude) is increased when mistakes are associated with primary punishment (Riesel, Weinberg, Endrass, Kathmann, & Hajcak, 2012), or when error confers loss of potential reward (Hajcak, Moser, Yeung, & Simons, 2005; Stürmer, Nigbur, Schacht, & Sommer, 2011). The ERN is also sensitive to interpersonal pressures, with larger amplitudes observed when performance is evaluated by an experimenter (Hajcak et al., 2005) or when feedback derides performance (Wiswede, Münte, & Rüsseler, 2009). Finally, the ERN increases when participants are autonomously motivated to perform a cognitive control task, perhaps because performance failure is more personally meaningful in these circumstances (Legault & Inzlicht, 2013).

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Neural monitoring is moderated by established moderators of emotion. Initial empirical support for this contention has been provided in a series of recent experiments. For example, reduced ERNs were found when participants misattributed their arousal to the anxiogenic side effects of a benign herbal supplement (Inzlicht & Al-Khindi, 2012), and when cognitive reappraisal strategies (c.f. Gross, 1998) instruct individuals to down-regulate emotional experience during performance (Hobson, Saunders, Al-Khindi, & Inzlicht, 2014). Furthermore, Bartholow et al. (2012) found that alcohol intoxication reduced ERN amplitudes, and did so by lowering performance-related negative affect, which follows from alcohol's known anxiolytic properties. Finally, facial feedback (enforced smiling) attenuates the ERN, suggesting that the embodiment of emotional experience also modulates neural performance monitoring (Wiswede, Münte, Krämer, & Rüsseler, 2009).

Self-Control as an Emotional Episode: The Regulation of Control

Thus far, we have reviewed the now considerable evidence arising from multiple levels of analysis—affective priming, self-report, facial EMG, and activation of the peripheral and central nervous system—indicating that performance monitoring

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processes reflect a negative affective response to conflicts and errors. In line with other recent suggestions, we suspect that the observed overlap in function likely reflects some evolutionary adaptation that is maintained because the integration of affective processing and self-control benefits the fitness of the organism (Gray, 2004; Pessoa, 2009). In broad terms, we suggest that the emotional experience of goal conflict drives animals to pursue "cognitive comfort," aiming to reduce negative affective states that arise when goals are threatened.

We define cognitive comfort as a psychological state that unites existing concepts in social and affective science. At its core, a drive for cognitive comfort accords with many basic theories of emotion, proposing that animals engage in pleasurable, rewarding, or beneficial pursuits, while avoiding aversive, unpleasant, or harmful stimulation (Barrett, 2006; Bradley, 2009; Frijda, 1988; Panksepp, 2008; Shackman et al., 2011). This drive for cognitive comfort is also consistent with social psychological theories of cognitive dissonance (Festinger, 1957). Cognitive dissonance refers to a psychological state of negative arousal that emerges when individuals experience conflicting cognitions (e.g., conflict between publicly expressing support for a policy and privately finding the policy objectionable), with considerable research suggesting that people are motivated to resolve dissonance to achieve a more comfortable psychological state, marked by cognitive consistency (Festinger, 1957; Gawronski, 2012). Thus, this desire to achieve cognitive comfort (or consistency) is a core socio-affective drive that, in our view, underlies variation in self-control. Initially, we consider how this drive for comfort might facilitate the up-regulation of control, with transient uncomfortable states heralding the imminent need to increase control.

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Affect as an Alarm Signal

Threatening emotional events gain "privileged access" to information processing (Hodsoll, Viding, & Lavie, 2011; Reeck & Egner, 2011), tuning the organism to information with high motivational significance, while limiting attention to less emotionally relevant information (Frijda, 1988). In this sense, the unpleasant experience of conflict and errors might alert the individual to the discrepancy between current events and desired goal states, in turn driving increased self-regulation to reduce the likelihood of future aversive experience (Botvinick, 2007; Holroyd & Coles, 2002). Therefore, this *affective alarm framework* (Inzlicht & Legault, 2014; see Figure 11.1) proposes that the emotional episode triggered by conflict drives increases in self-control levels, with control subsequently serving to remove conflict and regulate co-occurring performance-induced negative affect (Saunders, Milyavskaya, & Inzlicht, 2015).

By viewing the antecedents of self-control as an emotional episode, the affective alarm framework makes several novel predictions. Foremost, it is predicted that factors that moderate conventional emotional experience, including appraisal, attribution, and anxiolytic agents, should moderate not only neural reactivity to

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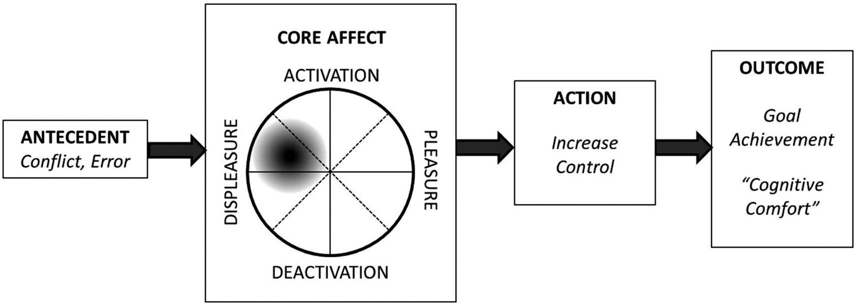

FIGURE 11.1 The affective alarm framework: Antecedent events (conflict, errors) produce a transient shift in core affect towards a state of negative valence, including a small to moderate increase from baseline levels of arousal (grey area). The individual is then motivated to increase control efforts in order to achieve "cognitive comfort": a state with less conflict between intentions, impulses, and actions.

goal conflict but also the extent of control implementation (Bartholow et al., 2012; Hobson et al., 2014; Inzlicht, Legault, & Teper, 2014; Teper, Segal, & Inzlicht, 2013). In the following section we will briefly review some of the empirical evidence supporting these behavioural claims.

Negative affect modulates conflict control. In addition to overall compatibility effects, such as the classic Stroop effect, attentional control levels are modulated as a function of conflict history (Gratton, Coles, & Donchin, 1992): Reduced interference effects are observed on trials preceded by incompatible stimuli (e.g., the word "BLUE" written in red ink), rather than trials following compatible targets (e.g., the word "BLUE" in blue ink). These *conflict adaptation effects* (Botvinick et al., 2001) are commonly suggested to reflect the operation of strategic control processes that aim to reduce the influence of conflict on performance (and not the result of mnemonic confounds; see Egner, 2007; Saunders & Jentzsch, 2014).

Strong evidence suggests that affective processes moderate these metrics of conflict control. For example, conflict adaptation effects are suppressed when spontaneous rewards are presented in the interval between trials of the flanker task (Van Steenbergen, Band, & Hommel, 2009, 2012), and this unexpected presentation of reward also attenuates the conflict-related EEG signals arising from the ACC (Van Steenbergen et al., 2012). Together these findings propose that rewards can reduce the "affective sting" of conflict, attenuating both neural monitoring signals and the extent that conflict drives the subsequent up-regulation of control. In one further study Van Steenbergen, Band, and Hommel (2010) experimentally manipulated mood on the dimensions of valence and arousal. Highlighting the specific role of negative affect in trial-to-trial control adjustments, conflict adaptation was increased for the low (vs. high) pleasure groups.

Very recent evidence also suggests that motivational orientations associated with negative information processing predict better conflict regulation. In brief,

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the motivational direction model (Davidson, 1995; Harmon-Jones, 2004) proposes two modes of motivational orientation—approach and avoidance—that largely modulate the way people interact with signals in the environment. Approach motivation is associated with positive emotional states, involving appetitive reward-seeking behaviours and extraversion, while avoidance motivation is associated with negative information processing, punishment sensitivity, and sadness (Elliot & Thrash, 2002; Gray & McNaughton, 2000; Tullett, Harmon-Jones, & Inzlicht, 2012). In line with the affective alarm framework, recent studies indicate that conflict control is more effective under the influence of avoidance, rather than approach, motivation. In one study, Shouppe, De Houwer, Ridderinkhof, and Notebaert (in press) reported reduced Stroop interference effects when response modality was consistent with avoidance motivation (backwards movement of a manikin), rather than with approach motivation (forward movement of a manikin). In a second study, Hengstler, Holland, van Steenbergen, and van Knippenberg (2014) demonstrated reduced conflict effects and increased conflict adaptation during the embodied induction of avoidance motivation (arm extension) relative to approach induction (arm flexion). Critically, these findings converge to suggest that increased attentiveness to negative affective signals increases sensitivity to signals of conflict, which in turn stimulates the up-regulation of self-control.

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Negative affective experience promotes error adaptation. In addition to conflict adaptation effects, online control adjustments are also observed after individuals make erroneous actions. Specifically, responses become slower (Rabbitt & Rodgers, 1977) and more accurate (Laming, 1968) following erroneous rather than correct actions. Such error adaptations putatively reflect temporary increases in response caution after errors, motivated in an attempt to reduce the likelihood of future mistakes (e.g., Botvinick et al., 2001; Dutilh et al., 2012; Laming, 1968; Saunders & Jentzsch, 2012; however, see Notebaert et al., 2009).

Akin to the effects observed in conflict adaptation, emerging evidence suggests that error adaptation is also modulated by affect. In one study, both posterror slowing and ERN amplitude increased during blocks where errors were punished with a loud, aversive sound blast (Riesel et al., 2012), while in another investigation the extent of posterror slowing and ERN amplitude increased when errors were associated with a loss of potential reward (Stürmer et al., 2011). Together, these studies propose that both neural sensitivity to errors and the extent of remedial error adaptation increase when external incentives raise the affective significance of accurate performance.

More directly implicating affective processing in error adaptation, Lindström et al. (2013) reported that error-related activation of the frowning musculature of the face (measured by EMG) predicts the extent of posterror slowing, strongly suggesting that the degree to which errors instigate a negative affect motivates subsequent increases in response caution.

Self-control and cognitive moderators of emotion. The affective alarm framework makes the novel prediction that factors known to moderate emotional episodes

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will impact upon the relationship between performance monitoring and control. Empirical support for these claims has emerged in a number of recent studies. In one investigation, neural error-reactivity (ERN amplitude) was correlated with performance accuracy only for participants who correctly attributed their negative affect to their mistakes, rather than the effects of an allegedly anxiogenic herbal supplement (Inzlicht & Al-Khindi, 2012). Similarly, the relationship between emotion-regulation strategies (up-regulation or down-regulation) and go/no-go false alarm rate is mediated by the extent that down-regulation instructions attenuate neural reactivity to errors (Hobson et al., 2014). Furthermore, Bartholow et al. (2012) found the relationship between the alcohol administration and posterror adjustment was mediated by the extent to which intoxication reduced performance-related negative affect. Thus, converging evidence suggests that the moderators of affective experience also reduce the extent that individuals adjust performance after goal conflicts.

Finally, the affective alarm framework also suggests that adaptive forms of emotional attunement, such as openness to threat, alter the relationship between monitoring and effective self-regulation. Supporting this hypothesis, a self-affirmation manipulation—viewing the self as good, worthwhile, and capable—designed to increase openness to threat (Sherman, Nelson, & Steele, 2000) also improved conflict monitoring and inhibitory control (Legault, Al-Khindi, & Inzlicht, 2012). This finding suggests that responding to self-control failure with openness facilitates goal achievement, potentially by allowing people to track their changing affective states while cutting short maladaptive cognitive responses to errors (e.g., catastrophization) that might interfere with successful performance (Beats, Sahakian, & Levy, 1996).

Summary. Considerable empirical evidence supports the relationship between integral negative affect and the up-regulation of self-control. Furthermore, the relationship between affective processing and increased control appears to be particularly strong when participants respond to self-control failures with acceptance. In contrast, the affective sting of errors appears to be felt less keenly when emotional experience is lessened by a number of cognitive factors, or when reward processing counteracts the aversive experience of conflict. Importantly, together these various results suggest that affective processing lends *vigour* to performance, alerting individuals to the need to act.

Negative Affect and the (Apparent) Limits of Self-Control

While the affective alarm framework proposes that integral negative affect invigorates self-control, we do not suggest that increased task engagement is an *inevitable* consequence of conflict. If we seek positive affective states, while avoiding harm, unpleasantness, or non-reward (Barrett, 2006; Bradley, 2009; Frijda, 1988; Panksepp, 2008), an equally adaptive response to aversive experience would be to evade challenging situations in favour of more pleasurable (or less aversive) pursuits

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(Panksepp, 2008; Proulx, Inzlicht, & Harmon-Jones, 2012). Consequently, negative emotional experiences evoked by conflict might decrease willingness to engage in subsequent control-demanding activities, particularly if such conflict threatens a goal that is not particularly rewarding or personally meaningful (Inzlicht, Legault, et al., 2014; Inzlicht, Schmeichel, et al., 2014). In the following section we overview a recent proposal that self-control failure reflects a shift in motivation, where individuals avoid effort in favour of more gratifying goals.

Ego depletion. A central question in the academic treatment of self-control has been whether the ability to self-regulate is limited by previous bouts of effortful control (Baumeister et al., 2007; Galliot & Baumeister, 2007; Hagger, Wood, Stiff, & Chatzisarantis, 2010). To investigate this question, researchers have developed the sequential-task paradigm, where laboratory participants first perform an initial task that challenges self-regulation (e.g., resisting tempting foods, completing a complex editing task, suppressing emotions to a distressing video) and then perform a secondary test of control (e.g., pain tolerance, the classic Stroop task, puzzle persistence). A common finding is that participants who perform a taxing control paradigm at the initial time-point perform worse on the secondary task than participant who had earlier performed a less effortful activity (e.g., Baumeister et al., 2007; Hagger et al., 2010; Inzlicht & Gutsell, 2007; Muraven, Tice, & Baumeister, 1998).

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The strength model of control. In the predominant treatment of the topic, Baumeister and colleagues (Baumeister et al., 2007; Muraven & Baumeister, 2000) have advanced a *strength model* of self-control, proposing that self-control depends on a finite physical resource that is depleted after effortful regulation. Thus, after an initial bout of control, individuals have less "fuel" remaining to regulate performance, leading to poorer inhibitory *strength* on a subsequent control task. Consistent with the resource concept, this phenomenon has received the title "ego depletion" and glucose has been proposed as the specific biological/energetic basis of self-control (Galliott et al., 2007). In the past two decades, the strength model have achieved a firm caché among experimental psychologists, with control strength evoked to explain failure in many real-life domains, including dieting (Baumeister, Bratslavsky, Muraven, & Tice, 1998), consumer behaviour (Baumeister, 2002), emotion regulation (Schmeichel, Vohs, & Baumeister, 2003), intramarital aggression (Bushman, De Wall, Pond, & Hanus, 2014), and even suicide (Vohs & Baumeister, 2002).

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While ego depletion has spurred great interest in self-control research, the conceptualization of control as a limited physical resource appears increasingly flawed (see Inzlicht & Schmeichel, 2012; Inzlicht, Schmeichel, et al., 2014; Kurzban, Duckworth, Kable, & Myers, 2013). Perhaps most saliently, glucose metabolism as a key determinant of self-control failure has been challenged in terms of both plausibility (Kurzban, 2010) and replicability (Molden et al., 2012). In fact, the mere act of rinsing the mouth with a glucose drink is sufficient to revitalize self-control (Molden et al., 2012). Beside these doubts, a number of "sugar-free" experimental manipulations moderate the deleterious effects of ego depletion on

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performance. Depletion effects are reduced when participants pray (Friese & Wänke, 2014), smoke a cigarette (Heckman, Ditre, & Brandon, 2012), watch a preferred television show (Derrick, 2013), or receive a surprise gift (Tice, Baumeister, Shmueli, & Muraven, 2007). Depletion is similarly attenuated when participants believe that self-control will be beneficial (Muraven & Slessareva, 2003), believe that the capacity for control is unlimited (Job, Dweck, & Walton, 2010), form explicit plans to implement control on the secondary task (Webb & Sheeran, 2003), and when participants engage in self-affirmation (Schmeichel & Vohs, 2009). Together these results indicate that variation in some limited control resource cannot explain depletion effects.

The process model of control. Inzlicht and colleagues (Inzlicht & Schmeichel, 2012; Inzlicht, Schmeichel, et al., 2014) have recently formulated an alternative: the *process model* or *shifting priorities* of self-control depletion. This model proposes that self-control exertion covaries with current motivational priorities: Individuals strike a balance between engaging control with tasks that provide a known source of reward (i.e., *exploitation*) and pursuing alternative contexts that might provide novel or more gratifying incentives (i.e., *exploration*) (Cohen, McClure, & Yu, 2007). In line with prior suggestions, Inzlicht, Schmeichel, et al. (2014) note that cognitive labour is aversive (Botvinick, 2007), bearing intrinsic disutility (Kool & Botvinick, 2013). Consequently, substantial external incentives are required to motivate the effortful pursuit of externally mandated tasks, such as those commonly used in studies of self-control.

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In contrast, prolonged cognitive engagement with unrewarding tasks occurs at the potential cost to opportunities in unexplored contexts (Kurzban et al., 2013), or to time invested in more intrinsically rewarding activities (Inzlicht & Schmeichel, 2013; Inzlicht, Schmeichel, et al., 2014). Therefore, as the subjective cost of control (Kool et al., 2010) increases with the cumulative experience of cognitive demands, the process model suggests that individuals down-value the importance of externally mandated tasks. This devaluation first results in reduced motivation to pursue the current goal, and concomitant reductions in attention and emotion aroused by subsequent conflicts arising in future performance (Inzlicht & Gutsell, 2007; Inzlicht, Schmeichel, et al., 2014). Importantly, however, this shifting priorities model also postulates that "depleted" states do not reduce motivation overall, but rather that individuals exhibit an increased desire for gratification and the exploration of new opportunities after longer periods of unrewarding self-control (Inzlicht & Schmeichel, 2013). Evincing this shift in priorities, Schmeichel, Harmon-Jones, and Harmon-Jones (2010) reported increased sensitivity for appetitive stimuli (dollar symbol) rather than non-appetitive stimuli (percent symbol) for participants who had previously exercised self-control compared to a "non-depleted" control group.

On a phenomenological level of analysis, motivational accounts of self-control further propose that prolonged effort in unrewarding contexts produces aversive states of mental fatigue (Inzlicht et al., 2014; Kurzban et al., 2013). At this point,

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it is important to clarify the proposed functional role of fatigue in self-control, and also highlight evidence indicating that protracted bouts of self-control promote fatigue, rather than some other negative emotional states.

Interestingly, akin to ego depletion, fatigue has often been characterized as a state of reduced energy that arises from overwork in a given domain (Bartlet, 1953, as cited in Hockey, 2013). However, also paralleling depletion literature, mental fatigue has more recently been identified as a psychological and emotional state linked to reduced motivation to perform sustained, cognitively demanding tasks (Boksem & Tops, 2008; Brown, 1994; Hockey, 2013; Lal & Craig, 2001). In a recent comprehensive overview of the psychology of fatigue, for example, Hockey (2013) postulated that fatigue is an unpleasant experience that arises when an individual experiences conflict between the perceived obligation to continue working towards a currently represented goal and the desire to switch to an alternative, potentially more rewarding activity. Thus, fatigue has been characterized as a negative emotion that provokes a form of cost-benefit evaluation, often interrupting effort dedicated towards the fatigue-inducing activity. Supporting fatigue as the key phenomenological outcome of depletion, a number of studies have indicated that sustained self-control effort produces subjective feelings of fatigue. In one example (Stewart, Wright, Azor Hui, & Simmons, 2009), participants experienced increased subjective fatigue after performing a difficult scanning task relative to participants who performed an analogous, but less demanding control exercise. Interestingly, these fatigued participants also experienced subsequent mental arithmetic exercises as more difficult than did control participants, indicating that effort also shapes perceptions of future performance. Specifically proposing fatigue—rather than some other affective state—as the principal phenomenological correlate of "ego depletion," a recent meta-analysis found that exercising self-control increased self-reported fatigue experiences ($d = 0.44$; 95 % CI [0.26, 0.63]), while depletion-related increases in negative affect were observed as a considerably smaller effect ($d = 0.14$; 95% CI [0.06, 0.22]) (Hagger et al., 2010). Together, these results indicate that exercising self-control over the longer term feels like fatigue.

But how might fatigue direct variation in control implementation? While fatigue—like other emotions—can be thought of as the output of situated valuation processes (c.f. Gross, 2015), motivational accounts of depletion propose that control-derived fatigue also facilitates the devaluation of continued effort towards the successful completion of the task at hand (Inzlicht, Schmeichel, et al., 2014; Kurzban et al., 2013). Therefore, these theories suggest that self-control appears to be limited after protracted effort because individuals are less *willing*—rather than less *able*—to work towards the attainment of goals that are perceived as unrewarding. Crucially, this motivational account can explain why engaging in a number of "sugar-free" gratifying activities appears to counteract depletion effects (e.g., Derrick, 2013), presumably by reducing effort-related fatigue states and leaving individuals sufficiently motivated to engage control effort (Inzlicht, Schmeichel, et al., 2014).

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Finally, it should be noted that fatigue states putatively motivate a shift away from subjectively unpleasant experiences, rather than cognitive demand *per se*. Consequently, the process model proposes that apparently effortful tasks (e.g., intense sport, chess, playing a musical instrument, and even complex data analysis) can be engaged in for longer if they are construed as pleasurable, rewarding, and inherently motivating to the individual (Deci & Ryan, 1985; Inzlicht, Legault, et al., 2014). Indeed, autonomous motivation—viewing the self in a causal role, deciding which action to take in line with inherent ambitions, objectives, and values—reliably moderates the effects of "ego depletion" in a number of studies (e.g., Moller, Deci, & Ryan, 2006; Muraven, Gagné, & Rosman, 2008).

Depletion and neuroaffective reactivity to errors. The shifting priorities account also proposes that fatigue states lead individuals to attribute less affective significance to the successful performance of externally mandated tasks (Inzlicht, Schmeichel, et al., 2014). Thus, this model predicts that integral negative affect relating to self-control failure will be attenuated after the onset of cognitive fatigue. In line with this suggestion, two studies have demonstrated less neuroaffective reactivity to errors (i.e., attenuated ERN amplitudes) on a secondary Stroop task after a prior task that taxes inhibitory control (Inzlicht & Gutsell, 2007; Wang, Yang, & Wang, 2014).

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In addition to proposing that people show reduced affective reactivity to failure during "have-to" tasks, these studies also suggest that neural conflict monitoring might mediate depletion effects. In a conceptually similar investigation, Boksem, Meijman, and Lorist (2006) also observed reduced neural monitoring (ERN amplitude) and poorer performance on a number of behavioural metrics of control (accuracy, overall reaction time, and posterror slowing) after participants engaged with a conflict task over an extended time period (> 2 hrs.). Importantly, however, these fatigue effects rapidly recovered within one short experimental block when fast and accurate performance had the potential to gain financial rewards. Crucially, these results suggest that cognitive fatigue reflects a change in motivational orientation (reduced task engagement), which is quickly reversed by external incentives that increase the gratification that can be obtained from engaging with a relatively mundane control task (Boksem & Tops, 2008).

Discussion

Initially, we proposed that self-control can be viewed as a type of emotional episode, and outlined the now considerable evidence suggesting that neural monitoring processes reflect negative evaluations of goal conflicts and errors. We subsequently asked what adaptive purpose this affective processing might serve, summarizing two viewpoints. The affect alarm framework postulates that integral negative affect improves control by orienting the individual to failure and goal conflicts, subsequently energizing task engagement and cognitive labour (Bartholow et al., 2012; Inzlicht & Legault, 2014; Schmeichel & Inzlicht, 2013). Conversely, the shifting

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priorities model of self-control proposes that the aversive experience of cognitive demand underlies a motivational shift, driving disengagement from cognitive labour while energizing the pursuit of more rewarding and immediately gratifying activities (Inzlicht & Schmeichel, 2012, 2013; Inzlicht, Schmeichel, et al., 2014). Thus, the negative experience of conflict underlies both the waxing and waning of motivations to tackle cognitive demand. How can negative affect lead to both increases and decreases in control?

Ultimately, and in line with many theories of emotion, the overarching goal of all animals is to avoid harm, unpleasant experience, and distress, while seeking out pleasure, rewards, and security (e.g., Barrett, 2006; Bradley, 2009; Panksepp, 2008). Furthermore, when faced with aversive cognitive demands during self-control challenges, we propose that the organism always seeks "cognitive comfort": a more satisfying state, free of the subjective unpleasantness associated with goal conflict. This comfort is sometimes, but not always, achieved by increasing control. In other situations, cognitive comfort can be achieved by disengaging from unpleasant, effortful tasks altogether, and increasing engagement with more immediately satisfying activities (Proulx et al., 2012). But why do individuals choose to increase control in one situation to achieve comfort, while in other situations control appears abandoned in favour of gratification?

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Affective Phenomenology, the Subjective Value of Control, and Self-Regulation

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In line with many recent accounts, we suggest that the willingness to engage control depends upon a balance between the subjective value of successful performance and the perceived effort of engaging control (Boksem & Tops, 2008; Kurzban et al., 2013; Shenhav et al., 2013). Furthermore, the value ascribed to accurate performance can arise from the influence of either intrinsic motivations (Deci & Ryan, 1985; Legault & Inzlicht, 2013) or external incentives (Chiew & Braver, 2011). When these intrapersonal or contextual factors lead individuals to feel invested in performance, control challenges are particularly salient, resulting in considerable task-related distress when self-control fails or is challenged. In such situations, disengaging from aversive cognitive demands would result in failure to achieve a desired, rewarding goal (or exposure to punishment), and, therefore, disengagement is unlikely to produce "cognitive comfort." Consequently, the most effective way to achieve cognitive comfort when working on "want-to" goals is to up-regulate control (see upper portion of Figure 11.2).

Next consider the inverse scenario, where neither intrinsic motivations nor external incentives promote engagement with the presently mandated task. Now that the inherent disutility associated with cognitive demands is not countered by a strong motive to engage control, the *cumulative* experience of aversive conflict putatively fosters a less engaged, unpleasant state, experienced as fatigue (Hagger et al., 2010; Stewart et al., 2009) (see Figure 11.2; lower panel). This fatigue likely

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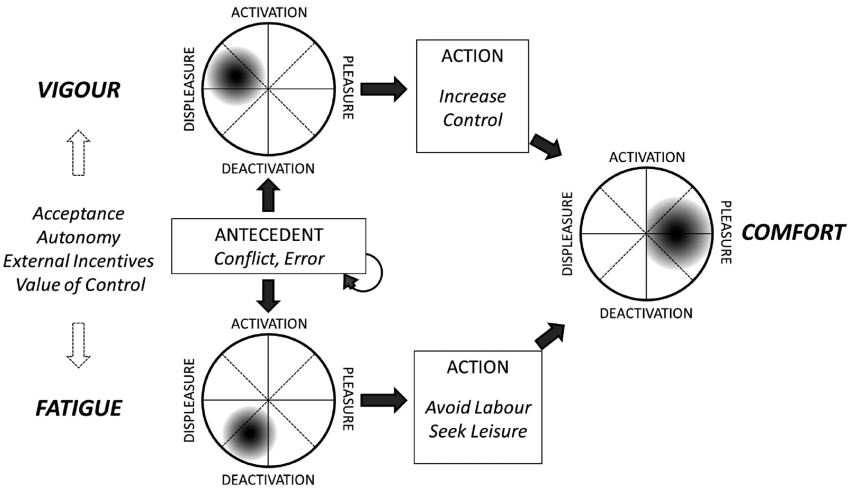

FIGURE 11.2 Variation in self-control as "comfort seeking." Vigour: An antecedent event (e.g., conflict, errors) that arouses a significant affective response initiates a change in core affect characterized by increased activation and negative valence (upper left circumplex). This "affective alarm" signals the need to increase control within the current task context and, thus, energizes control effort. Fatigue: Over time, the repeated experience of conflict (recursive arrow) can also drive fatigue, a more tonic state of negative valence and reduced activation (lower left circumplex). This unpleasant state signals that the current task is unrewarding, driving the pursuit of more immediately gratifying activities and reductions in conflict monitoring for the externally mandated task. The extent to which the occurrence of an antecedent event drives core affect towards a more activated or deactivated state depends on a number of moderating factors, including acceptance, autonomy, external incentives, and the overall subjective value of control. Crucially, both actions (increase control, seek leisure) are considered adaptive responses that seek to restore more pleasurable states of cognitive comfort (rightmost circumplex).

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motivates individuals to consider the value of continuing to pursue the current goal relative to other options (Hockey, 2013), potentially highlighting that sustained effort in this unrewarding context can result only in further disutility through the aversive experience of cognitive demand (Kool et al., 2010). Instead, cognitive comfort might be best achieved by withdrawing from unrewarding goals, and instead approaching other, more gratifying activities (Inzlicht et al., 2014; Schmeichel et al., 2010; see Figure 11.2, lower panels). In this light, moderation of depletion by sources of comfort—such as comedy (Tice et al., 2007), prayer (Friese & Wänke, 2014), smoking (Heckman et al., 2012), spontaneous gifts (Tice et al., 2007), or preferred TV (Derrick, 2013)—might all be effective due to their salutary influences on the unpleasant fatigue states caused by the exertion of self-control.

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The Role of Neuroaffective Responses to Conflict

While the affective alarm framework speaks directly to the nature of neural performance monitoring processes, we also propose that changes in neuroaffective responses to goal conflict not only mediate "depletion" effects (Inzlicht & Gutsell, 2007) but also may underlie the moderation of cognitive fatigue when intrapersonal and contextual factors re-invigorate the affective alarm signal.

First, in line with recent proposals that the ACC computes the expected value of control (Shenhav et al., 2013), we suggest that monitoring processes steadily become disengaged after repeated exposure to conflict and cognitive demand, especially when individuals have little intrinsic or extrinsic motivation for the task at hand (Boksem et al., 2006; Inzlicht & Gutsell, 2007; Wang et al., 2014). Thus, rather than reflecting the metabolic consumption of central control resources (Galliott et al., 2007), this process more likely arises out of the steady attenuation of the motivational significance of control challenges during unrewarding task performance.

Changes in motivation, however, are also flexible: Manipulations serving to increase the subjective value of control also increase the affective alarm signal to control failure and moderate "ego depletion" effects. For example, experimental manipulations of both autonomous motivation and self-affirmation reduce depletion effects (e.g., Muraven et al., 2008; Schmeichel & Vohs, 2009) and increase neuroaffective reactivity to errors (ERN amplitude) (Legault et al., 2012; Legault & Inzlicht, 2013). Critically, these findings propose that such intrapersonal factors might serve sustained self-control efforts by energizing emotional engagement with proximal goals. In addition to intrinsic motivations, external incentives that increase the value of control also modulate the reactivity of the affective alarm to control failure (Hajcak et al., 2005; Riesel et al., 2012; Stürmer et al., 2011), and re-invigorate both control and performance monitoring after fatigue (Boksem et al., 2006). Importantly, in such a context, seeking cognitive leisure to alleviate fatigue would result in reduced potential to obtain external rewards, unlikely to align with the overarching goal to achieve cognitive comfort.

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Concluding Remarks and Future Directions

By viewing variation in self-control as "comfort-seeking" behaviour, we are able to explain why negative affect might underlie both increased cognitive vigour *and* fatigue. Importantly, through conceptualizing both increased engagement with current task demands and task-disengagement in favour of more gratifying pursuits as forms of emotion regulation, we suggest that both reactions to conflict are adaptive responses that promote the well-being of the individual. In particular, this view is contrasted with the strength model of control, where "depletion" putatively reflects the inherent *fallibility* of self-regulation (Baumeister et al., 2007). While our affective-motivational analysis has the potential to unite previously disconnected areas of research (e.g., affective science, cognitive neuroscience, and

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self-control research), our preliminary model of variation in control is also generative, raising a number of questions that can be tackled in ongoing research. Finally, we briefly identify three core areas of our account that can be readily investigated in future studies.

First, we propose that repeated self-control performance is experienced subjectively as fatigue, a state that subsequently drives motivational switching towards the pursuit of gratification (Inzlicht et al., 2014; Schemichel et al., 2010). Importantly, ongoing research could more directly test this proposition. More specifically, as also noted by Hagger et al. (2010), while existing studies indicate that fatigue states arise out of prolonged bouts of self-control (e.g., Stewart et al., 2009), it is currently unknown if these subjective experiences mediate behavioural depletion effects on subsequent effortful tasks. Consequently, future research should aim to closely relate intra-individual variation in affective phenomenology to variation in control implementation, from its success to its apparent weakness.

Second, we propose that task-related sources of conflict, such as errors or competing impulses, have a reduced ability to trigger affective arousal once individuals have entered an unmotivated, "depleted" state. As with the phenomenology of control, this psychophysiological hypothesis is directly testable. Specifically, future investigations of depletion could test if repeated exposure to conflict in unrewarding contexts leads to reduced error-related peripheral arousal, as measured by EMG, pupilometry, or skin conductance responses.

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Third, if fatigue motivates the switching of behaviours to increase the pursuit of reward, is this gratification seeking reflected by neurophysiological correlates of reward sensitivity? Several ERP components have been related to the processing of reward (Proudfit, 2014; Yeung & Sanfey, 2004), and, therefore, if states of depletion promote gratification seeking (Inzlicht, Schmeichel, et al., 2014), it might be predicted that these neural correlates of reward sensitivity will be potentiated to rewarding feedback signals after individuals have become fatigued. Such a finding would complement extant behavioural investigations indicating that exerting self-control leads to the increased saliency of appetitive stimuli (Schmeichel et al., 2010).

It is our hope that future research will continue to advance theories of self-control by closely examining the integration of affective and cognitive processes, in turn providing a more comprehensive understanding of the apparent strengths and limitations of these important regulatory processes.

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