2 The Roles of Predictive and Reactive Biobehavioral Programs in Resilience

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In this chapter we propose a theory in which behavior (broadly comprising relevant cognition, emotion, and behavior) and physiology are coordinated and integrated by a number of separate behavioral and physiological programs, for convenience termed here ***biobehavioral programs***. We propose that resilience may vary over time and between persons, depending on which program exercises control over behavior. More specifically, we will describe two main biobehavioral programs that control behavior adaptively in low-predictable and in highly predictable environments respectively. Behavior and emotions guided by the first program are highly reactive, while behavior and emotions controlled by the second program are guided by models of behaviors that are optimal in their own contexts and that have been consolidated in memory to form context models. Here, we will argue that interventions and experiences that increase resilience may accomplish this by shifting control from the *reactive* program to the *context model* program.

Ventral corticolimbic control pathways in the brain are crucially involved in reactive behavioral control that includes fast associative learning, seen as highly adaptive in unpredictable environments. By contrast, dorsal corticolimbic control pathways are specialized for slow stable learning that is adaptive in highly predictable environments. Dorsal control pathways guide behavior in a feed-forward fashion by using models of the context that are stored in long-term memory. The reactive system produces a momentary, immediate sense of awareness in which emotional events and stimuli are experienced as close in time and space. Because of this immediacy of emotional experience, reactive control is associated with emotion-focused coping. By contrast, in episodes where context models guide and control behavior, emotional experience is less immediate and overwhelming. In addition, context models that are successfully used in predictive control will tend to include representations of positive experiences and outcomes. This positive bias and these less intense emotions enable active coping through confronting both negative and positive affective events and stimuli. We will discuss how these programs are involved in the development of resilience.

We propose that, during evolution, biobehavioral programs developed to orchestrate different aspects of behavioral and physiological control systems; each program adapted to a particular set of contexts and conditions (Tops, Boksem, Luu, & Tucker, 2010). Aspects of the control systems include arousal, information processing biases, action control, specific cognitive operations, and, importantly, specific motivation. We draw on Panksepp's (1998) levels of affective mind-brain organization to illustrate the depth and breadth of these biobehavioral programs, which we see as integrating *primary process emotions* that arise from evolutionarily provided subcortical operating systems, *secondary process emotions* that reflect basic emotional learning and memory processes as reflected in classical and operant conditioning, and *tertiary process emotions* or the higher emotional functions of thought and deliberation included in episodic/autobiographical memories, symbolic thought, and communication (Panksepp, 1998; Panksepp, Chapter 1, this volume). Our discussion does not focus on differences between primary, secondary, and tertiary process aspects of emotions but on ventral and dorsal corticolimbic system programs in which each combines specific elements at all three process levels.

Finally, we propose that resilience can be increased in reactive individuals (i.e., persons in whom the reactive control program tends to dominate) by increasing capacities to shift toward context model biobehavioral programs. The brain appears equipped with mechanisms to make this shift, and individuals often display such a shift during skill acquisition and performance learning. Resilience may be increased through the application of similar learning mechanisms to the control of behaviors and emotions in negative environments.

In the following sections, we first describe the two types of control systems, reactive and context model programs. Then we discuss mechanisms for shifting between these two control systems and discuss how they bolster resilience. Finally, we review evidence for how this shift may be applied to strengthen resilience through certain interventions, experiences, and behaviors such as emotion regulation, impulse control or "cool" vs. "hot" control, mindfulness meditation, and certain psychopharmacological agents. We discuss the evidence for how this shift may be involved in strengthening resilience through the cultivation of positive emotions. We also consider the relation of our model to other theories that explain the effects of emotions on cognition and resilience.

THE VENTRAL AND DORSAL CORTICOLIMBIC CONTROL PATHWAYS OF THE REACTIVE AND CONTEXT MODEL BIOBEHAVIORAL PROGRAMS

We have argued for an evolutionary process underpinning the development of partially separate ventrolateral and mediodorsal control pathways that supported two behavioral programs adapted to different environments (Tops & Boksem, 2011a, 2012; Tops et al., 2010), as illustrated in Figure 2.1.

The first program, termed the reactive program, incorporates the ventral corticolimbic control pathways, including inferior frontal gyrus (IFG), anterior insula (AI), amygdala, and anterior medial temporal lobe. The reactive program promotes fast associative learning that is adaptive in low-predictable environments. The reactive program contrasts with the second program, termed the context model program, which incorporates the dorsal control pathways that include posterior cingulate cortex, precuneus, posterior medial temporal lobe, and dorsolateral prefrontal cortex. The dorsal control pathways are specialized for guiding behavior with context models that are formed and kept stable by slow learning, a specialization that is adaptive in predictable environments. Context models are formed in long-term memory by the predictability of the environment/context.

In low-predictable environments, effective context models generally cannot be formed quickly nor used to control behavior quickly in adaptive ways. Instead, behavior is guided reactively by momentary feedback from environmental stimuli through ventral corticolimbic control. This reactive guidance by momentary environmental stimuli is associated with attention focused on stimuli that are urgent and close in time and space. Those stimuli can be positive ("I have to catch that reward that is in my reach before it gets away") or negative ("I have to get away from that danger before it gets me, because I'm in its reach"). By contrast, there is less urgency and focus on the moment (i.e., less narrow, more global focus

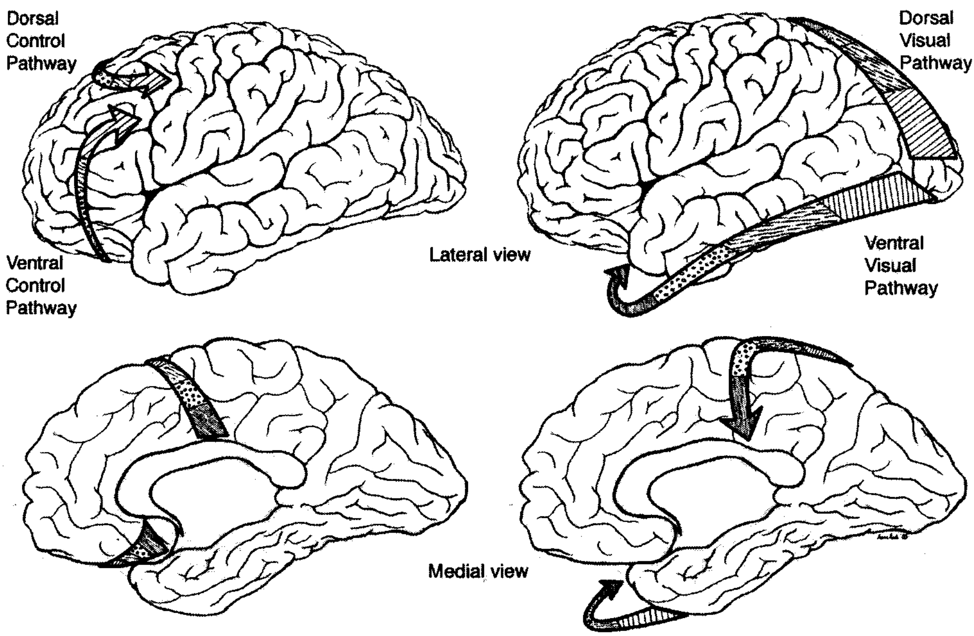

Figure 2.1 *Left:* Primary direction of corticolimbic traffic for organizing output from limbic integration toward specific action modules in the motor cortex. Two separate control paths are routed from limbic networks through the frontal lobe to the motor cortex. A ventrolateral pathway proceeds from the olfactory cortex through the orbital frontal lobe to the lateral frontal cortex before reaching the ventral premotor and motor cortices (ventral/bottom arrows). A mediodorsal pathway proceeds from the cingulate gyrus through the medial frontal cortex to the dorsolateral frontal cortex to the premotor and motor areas on the lateral convexity of the hemisphere (upper/dorsal arrows). *Right:* Primary direction of corticolimbic traffic for integrating perception from specific modules in the sensory cortex (in this case the arrows start from the visual area) toward the limbic cortex shown for dorsal (upper arrows) and ventral (bottom arrows). From Tucker (2007), copyright.

in time and space) when behavior is guided by context models in feed-forward fashion ("I will plant these seeds now, so that I have food for the coming winter, just like last year," or "I will repair the fence around my chicken pen, so that foxes will not steal the eggs"). Table 2.1 summarizes the ventrolateral and dorsomedial control models.

Classical work has shown that states of affective arousal carry resource information (physiological resources such as glucose levels and the condition of muscles, as well as social resources) and that these states are associated with implicit perceptions of coping abilities (Thayer, 1989). Only in low-predictable environments is it necessary to have a continuous readout of the level of available resources to inform immediate action. In the ventral corticolimbic control pathway, via the IFG and AI, information about the level of resources is combined with emotional or "drive" information that biases the direction of action either towards (i.e., approach behaviors like craving, hunger, love, trust) or away from (i.e., avoidance behaviors like disgust, pain, distrust) a target object (Tops & de Jong, 2006; Tops et al., 2010). This directional drive property may have developed from functions of the gustatory cortex that is situated in the insula. The directional drive bias and information about resources are further combined with relevant target information and, depending on circumstances, with priming or preparation for action responses and with matching autonomic responses. Together, the continuous readout of the direction of drive, resource levels, and orientation to potential targets enables fast, opportunistic action on the spur of the moment.

Table 2.1 Comparison of Ventral and Dorsal Control Pathways: Summary Features of Ventral Corticolimbic Control and Dorsal Corticolimbic Control

Ventral corticolimbic control pathway	*Dorsal corticolimbic control pathway*
Environment:	
Low predictable	High predictable
Behavior:	
Direct sensitivity to + and – environmental influences or stimuli	Less direct responsivity to environmental influences or stimuli
Reactive guidance—by momentary feedback from environment	*Predictive context model* guidance formed in long-term memory feed-forward model
Attention focus is on urgent stimuli, narrow	Less urgent, less narrow
Close in time and space	More global focus in time and space
Focus on negative or positive stimuli	Positive emotional bias
Fast associative learning: fast opportunistic action, spur of the moment	Slow learning previous experience with specific context; episodic memory, prospective self-related; simulate and predict future events that build on previous experience (context models)
Ventral control bias = distressed in most environments	Dorsal control bias = not distressed in most environments
Brain functions:	
Inferior frontal gyrus (IFG)	Dorsolateral prefrontal cortex (dPFC)
Anterior insula (AI)	Posterior cingulate cortex
Amygdala	Precuneus
Anterior medial temporal lobe	Posterior medial temporal lobe
Ventral striatum	Dorsal striatum

The posterior cingulate cortex and precuneus, which are connected to the dorsal striatum and dorsolateral prefrontal cortex, are considered the dorsal endpoint of the rostral-ventral to caudal-dorsal gradient within the cortex, and as mediators of the dorsal control pathway. This may seem at odds with findings that identify these areas as important for self-reflection and as central to the "default mode network" that is active at rest and deactivates during many cognitive tasks. However, it is important to realize that self-reflection may be possible only at rest, and when performing habitual actions (in which the dorsal striatum is important), since attention in both cases is not involved with other processes. Self-reflection may involve activation of memories of the self in contexts (context models). Although retrieval and action control may partly dissociate during self-reflection, true context model-guided control is informed by previous experiences with specific contexts and involves engaging in increasingly automated or habitual behaviors. The default mode network has been proposed to support the ability to perform internal mentation by providing a platform for assembling dynamic internal mental models and scenarios (Buckner & Carroll, 2007). Typically, these scenarios would contain elements of autobiographical episodic memory and self-related prospective thoughts. It has also been suggested that the purpose of continuous internal mentation may be to act as a simulator and predictor of future events that are built from previous experiences (i.e., context models).

In many situations and for many tasks, dorsal and ventral systems will collaborate and interact in the control of behavior. For example, findings support the interactions between IFG and dorsal frontal areas. When IFG implements reactive (momentary) immediate action according to the information from contextual signals, dorsal frontal cortical areas simultaneously implement "predictive" episodic motivation control and sustain control over behavioral episodes. The dorsal control is achieved through information conveyed from temporally remote events (or context models), from the history of actions and outcomes, and from implementation of feed-forward control of behavioral patterns and their integrated action sequences. However, temporary as well as relatively stable biases for reactive control may result from temperament, unpredictable dangerous or urgent situations, perceptions of unpredictability after trauma or inconsistent parenting, and interactions between these factors. By contrast, a bias for context model-guided control may stem from a different temperament, and may follow consistent parenting and a predictable, secure early environment that favors exploration and the development of context models (i.e., internal working models of Bowlby's attachment theory, 1988).

DORSAL AND VENTRAL MECHANISMS OF RESILIENCE

The reactive and context model behavioral programs associated with ventral and dorsal control systems, respectively, have evolved because they are adaptive in certain environments and circumstances. Both the dorsal and the ventral programs are associated with talents and sources of resilience. However, while the reactive ventral programs are directly sensitive and responsive to both negative and positive environmental influences (including the social environment), the dorsal programs make use of context models and are, thus, less responsive to environmental influences. Because of this different responsivity of these biobehavioral programs, individuals who are biased towards dorsal control will generally not be distressed in most environments and adapt well. On the other hand, individuals who are biased toward ventral control may experience distress in many different environments. Such individuals may benefit from an increased capability to shift to dorsal control. We will focus on increasing resilience through shifting from ventral to dorsal control (i.e., from reactive to context model), because we believe this process is involved in various interventions or mechanisms that bolster resilience. We will discuss several examples in the following sections.

We propose that resilience can be increased in reactive individuals by increasing capacities to shift to context model biobehavioral control programs. The brain is actually equipped to make this shift, a shift that is often evident during the learning of skills. Resilience may be increased by similar learning mechanisms that are applied to behavioral and emotional control in negative environments. Human and animal studies identify three elementary learning systems in the stages of skill acquisition. One system represents rapid and focused acquisition of new skills during threats and violations of expectations. The second system is a gradual process of updating a configural model of the environmental context. These two learning systems correspond to the ventral and dorsal corticolimbic control pathways discussed above. During learning, the ventral system is strongly involved in the early phase of learning, while the dorsal control system comes online later as learning progresses (Luu, Shane, Pratt, & Tucker, 2009).

The engagement of each system during the course of learning is dependent on the nature of the events within the learning task. Certain tasks may express a third system, the habit-formation system in the dorsal striatum. Recent behavioral studies in both humans and rodents have found evidence that performance in decision-making tasks depends on two different learning processes: one encodes the relationship between actions and their consequences and the second involves the formation of stimulus–response associations (Balleine & O'Doherty, 2010; Luu, Shane, Pratt, & Tucker, 2009). These two learning processes are thought to govern goal-directed and habitual actions, respectively. It appears likely that cooperation or competition between these sources of action control depends on the third learning system, which incorporates the cortico-basal ganglia network within which the striatum is embedded and that mediates the integration of learning with basic motivational and emotional processes (Balleine & O'Doherty, 2010; Luu et al., 2011).

Neurophysiological studies on connectivity pathways in animal brains (Haber, Fudge, & McFarland, 2000; cf. Joel & Weiner, 2000) demonstrate an interface between ventromedial (limbic), central dorsal (associative), and dorsolateral (motor) striatal regions via the midbrain dopamine cells (ventral tegmental area, substantia nigra), as well as via cortical areas, which form an ascending spiral between regions, as illustrated in Figure 2.2.

We argue that this ascending spiral mediates functional shifts from reactive ventral control towards dorsal feed-forward and context model-guided control, to habitual control (Tops & Boksem, 2012). In reactive persons, resilience can be increased by a shift from reactive ventral to dorsal context model-guided control. We will discuss some examples in the following sections.

SHIFTING FROM REACTIVE TO CONTEXT MODEL CONTROL: IMPLICATIONS FOR RESILIENCE

A host of intervention strategies have been developed to bolster individuals' capacities to manage difficult life circumstances and challenges. Included among these strategies are positive affect enhancement and emotion regulation, cognitive reframing, and mindfulness meditation, each of which may increase resilience in reactive individuals by enabling a shift from reactive ventral to dorsal context model control. In the next sections, we discuss the mechanisms whereby these strategies may contribute to resilience strategies.

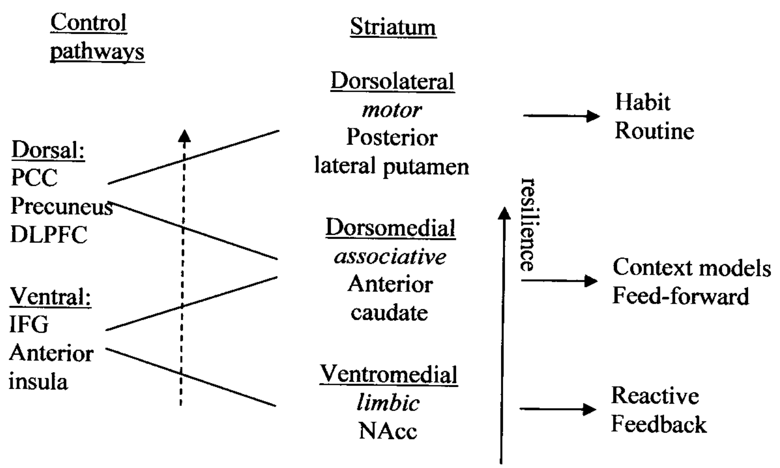

Figure 2.2 Schematic representation of an interface between ventromedial (limbic), central/dorsomedial (associative), and dorsolateral (motor) striatal regions, via ventrolateral corticolimbic and dorsomedial corticostriatal control pathways and via the midbrain dopamine (DA) cells (ventral tegmental area and substantia nigra, not shown), which form an ascending spiral between regions. The ventromedial striatum influences the central striatum, and the central striatum influences the dorsolateral striatum. This chapter argues that this ascending spiral mediates functional shifts from reactive ventral control towards dorsal feed-forward and context model-guided control, to habitual control. Resilience in reactive persons can be increased by the shift from reactive ventral towards dorsal context model-guided control. IFG = inferior frontal gyrus (ventrolateral prefrontal cortex); PCC = posterior cingulate cortex; DLPFC = dorsolateral prefrontal cortex; NAcc = nucleus accumbens/ventral striatum. Adapted from Tops and Boksem (2012).

Positive Affect

Positive and Negative Affect and Attentional Scope

One way to increase resilience is to cultivate positive affect, which is thought to broaden attentional scope and mindsets (e.g., Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008). Some of the theories on affective influences over attentional scope and resilience originated in part from earlier work by Tucker, Luu, and colleagues (e.g., Luu et al., 2011; Tucker, Luu, & Pribram, 1995), as does our own theory. We propose that certain positive affects increase resilience by inducing a shift from reactive ventral control to dorsal context model control. However, while other affective theories focus on dichotomies, our approach distinguishes between three classes of affects that each reflect a different underlying system: (1) reactive approach-related affects that are in most cases positive; (2) reactive avoidance-related affects that are in most cases negative; and (3) affects related to context model control that are associated with optimism and a positive affective bias but that also allow the simultaneous confronting of both negative and positive affective events and stimuli. We will argue that our present model incorporates classical findings in this field, as well as recent findings not covered by previous models.

Friedman and Förster's (2010) literature review shows that positive emotional states and implicit affective cues expand the scope of attention (global focus) and that negative emotional states and implicit affective cues constrict the scope of attention (local focus) at both the perceptual and the conceptual levels. They conclude that a large and growing body of research supports the model and the assumptions that originated from Tucker and colleagues' neuropsychological work and theory (e.g., Derryberry & Tucker, 1994; Luu, Tucker & Derryberry, 1998; Tucker & Williamson, 1984). The early studies were, thus, collectively inspired by a set of converging empirical and theoretical contributions (e.g., Fredrickson et al., 2008; Luu et al., 2011; Luu et al., 2009; Schwartz, 1990).

From the theory of Tucker, Luu, and colleagues, our present model retains the hypothesis that the systems associated with the context models are biased towards positive emotion, optimism, self-efficacy, and confidence because the context models are based on previous predictive successes and positive outcomes. Our model also retains a reactive system that focuses on avoiding punishment and harm, but makes one important adjustment in adding ***reward*** to the reactive system in which both the avoidance of harm and seeking reward narrow space and time. This additional appetitive reactive reward-oriented system incorporates recent findings of Gable and Harmon-Jones within the expanded framework of our model. These authors report several studies in which reactive positive (appetitive, e.g., hunger) reward motivation facilitates a local focus (Gable & Harmon-Jones, 2008; Harmon-Jones & Gable, 2009). Our model also incorporates findings from Förster and colleagues (e.g., Förster, 2009; Förster & Tory Higgins, 2005; Liberman & Förster, 2009). Their results show that a global attentional focus is associated with larger psychological distance in time and space, "promotion focus," prospection, high power, and a focus on similarities (which is compatible with the formation of configural context models). In contrast, a local attentional focus is associated with small psychological distances in time and space, "prevention focus," low power, and a focus on differences (consistent with ventral object processing).

There is an inherent positive bias in dorsal/feed-forward control. However, this does not involve exclusion or avoidance of negative affect. On the contrary, expectations of positive outcomes enable the individual to confront negative affect. It would not be adaptive or plausible if negative affective information were excluded from context models. Context models are formed by averaging and configurally integrating many neutral, positive, and negative affective experiences with a bias towards positive successful outcomes. Hence, separate positive and negative affective dorsal systems do not seem to make sense, nor does an exclusively positive affective system that excludes negative affective experience. While the dorsal system integrates positive and negative affect and confronts both with a positive bias, for ventral reactive systems it makes more sense that positive/approach and negative/avoidance affects are processed at least partly by separate systems, as is supported by evidence (Small, Zatorre, Dagher, Evans, & Jones-Gotman, 2001).

Notice that, because approach and avoidance actions are opposite in direction and thus mutually exclusive, dominance of ventral reactive control is characterized by a single bipolar dimension with highly inversely coupled affect (positive in reactive approach, and negative in reactive avoidance). In contrast, in dorsal context models both positive and negative emotions are integrated and confronted. This means that, in context models, positive and negative emotions do not form the opposite poles of a single dimension, but can occur independently and simultaneously. We will elaborate on this in the next section.

This pattern is evident in research on optimism. Optimists do not avoid negative information, especially not when confronting negative affect and information that is important for active coping. Rather, avoidance of negative information is related to passive coping, while optimism and active coping are associated with processing both positive and negative information and affect (e.g., Aspinwall, Richter, & Hoffman, 2001). Nevertheless, there remain both a positive bias in the dorsal control and a special importance that is placed on the negative reactive avoidance system. It should be noted that the negative reactive avoidance system is critical for survival in some acute situations. This explains why the literature supports the positive affect–global focus bias and the negative affect–local focus bias, while certain more subtle negative affect–global biases and positive affect–local biases have been discovered only recently.

Related distinctions between different types of positive affects are offered by several investigators. Drawing on the review by Derryberry and Tucker (1994), the broaden-and-build theory of Fredrickson (1998) describes positive affect in a way that is consistent with the predictive context model control system. According to this theory, some positive emotions broaden an individual's momentary thought–action repertoire: joy triggers the urge to play, interest triggers the urge to explore, contentment activates the urge to savor and integrate, and love activates a recurring cycle of each of these urges within safe, close relationships. The broadened mindsets arising from these positive emotions are contrasted with the narrowed mindsets activated by emotions associated with specific action tendencies, such as attack or flight (by emotions associated with reactive approach or avoidance; see also Gable & Harmon-Jones, 2008). Panksepp (1998) similarly recognizes a positive affect system associated with play and seeking beyond simply obtaining rewards. These theories along with our model make the distinction between the positive affect related to reactive approach and the kinds of positive affects that are adaptive in stable, predictable, or comfortable environments and that allow for a broadening of attention and cognition (Carver, 2003; Fredrickson, 1998; Gable & Harmon-Jones, 2008; Panksepp, 1998). This broadening of attention in the dorsal mode serves the function of guiding exploratory behavior by integrating and constructing context models, reading contexts, and flexibly and optimally selecting and switching between context models. We suggest that Fredrickson's "building" in the "broaden-and-build theory" reflects the building and utilization of context models that "build" and bolster resilience.

The Independence or Bipolarity of Positive and Negative Affect

The present model can explain another resilience-related aspect of positive and negative affect that is covered by Zautra and colleagues' dynamic model of affect (Reich, Zautra, & Davis, 2003; Zautra, Berkhof, & Nicolson, 2002; Zautra, Reich, Davis, Potter, & Nicolson, 2000). Reich, Zautra, and Davis argue that, when the environment is safe and predictable, it is relatively easy for people to engage in complex, differentiated, and multidimensional processing of the surrounding environment and of their own positive as well as negative affective reactions in response to that environment. However, in more demanding and unpredictable situations attention becomes more focused on the most immediate and necessary behaviors and information in the environment. Thus, perceptions and attributions become more narrow and the experiences of positive or negative states "collapse into a single bipolar dimension with highly inversely coupled affect" (Reich et al., 2003, p. 70). The inverse relationship between positive and negative affect in times of stress seems to reflect a direct relationship between the severity of the stress and the strength of the bipolarity (Bisconti, Bergeman, & Boker, 2004). For example, in longitudinal studies of people suffering from chronic pain syndromes, Zautra and Smith (2001) found that, when pain was more pronounced, the presence of positive affect was predictive of a weaker relationship between pain and negative affect. In other words, as pain escalates, positive affect appears to play an increasing role in the regulation of negative affect (Zautra & Smith, 2001). In a study that controlled for current levels of distress, recently bereaved resilient individuals had weaker correlations between self-reported negative affect and positive affect, suggesting relatively greater independence in affect and less bipolarity (Coifman, Bonanno, & Rafaeli, 2007). By contrast, for those individuals who had chronically elevated symptom levels similar to complicated (prolonged, unabated) grief reactions, positive and negative affect were more strongly inversely correlated, suggesting less independence between affects and greater bipolarity (Bonanno, Goorin & Coifman, 2008).

Our model predicts the same pattern as the dynamic model of affect. Because of the immediacy of emotional experience, reactive control is associated with emotion-focused coping and with related simplified and rapid responding by systems that are specialized for approach vs. avoidance actions. By contrast, the emotional experience in predictive control is less immediate and overwhelming. Moreover, the successful context models that are shaped and used in predictive control will tend to include representations of positive experience and outcomes. To repeat Aspinwall et al.'s (2001) findings on optimistic individuals, positive bias and less intense emotional experiences enable active coping through a confrontation of both negative and positive affect. Figure 2.3 shows that in dorsal systems both positive and negative affective information are stored in and retrieved from highly integrated context models, while ventral systems have specialized antagonistic reactive approach and reactive avoidance systems that create the experience of a bipolar reactive affect dimension.

Although the reactive approach and avoidance systems express their characteristic emotions and motivations, they are not exclusively positive or negative (Friedman & Förster, 2011). Nevertheless, it can generally be said that reactive approach will be associated with positive emotions such as stimulus-triggered appetition and that reactive avoidance will be associated with negative emotions such as acute fear. Our model is compatible with the dynamic model of affect in that our model predicts that a shift from reactive ventral control to context model-guided dorsal control will decrease the bipolarity of positive and negative affect and increase resilience (e.g., Coifman et al., 2007).

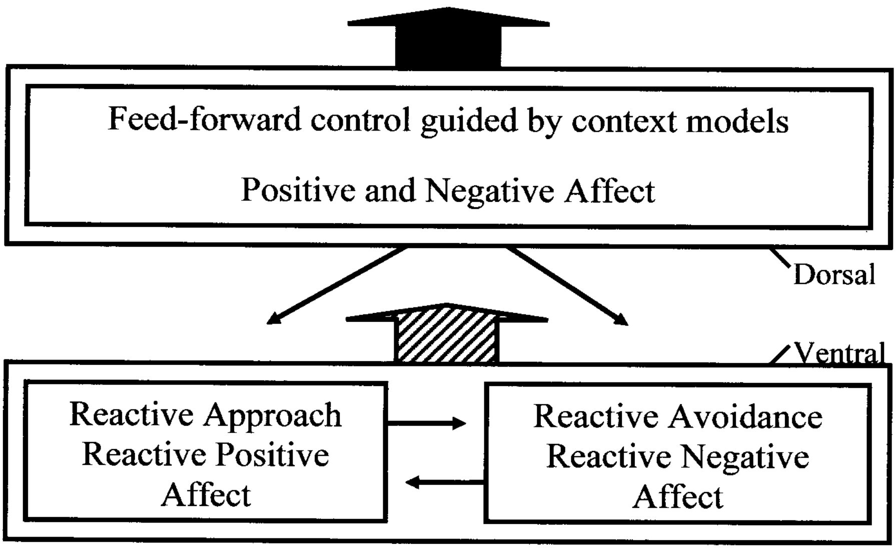

Figure 2.3 Positive and negative affect as associated with three temperamental influences on behavior that reflect different behavioral programs. A reactive system for approaching rewards and a reactive system for avoiding threats or punishment form a bipolar reactive approach–avoidance dimension, and both interact, collaborate, and compete with, and are dampened by, a system guided by context models. Guidance by context models allows for active coping and increased resilience in which both positive and negative affective contents can be confronted simultaneously. This figure is adapted from Tops, Boksem, Luu, & Tucker (2010) and inspired by Figure 1 in Carver, Johnson, and Joormann (2009), who, in turn, noted the influence of Mary Rothbart and others.

Reactive Affect and Perceived Resources

The apparent direct relationship between the severity of the stress and the strength of the bipolarity (previous section; Bisconti et al., 2004) is predicted by our reactive ventral and dorsal context control model discussed earlier. To review briefly, classical studies demonstrate that affective arousal states carry resource information (physiological resources of glucose levels, muscle condition, etc.; social resources). These arousal states are linked to implicit perceptions of coping abilities (Thayer, 1989). In the IFG/AI cortical pathways, the information about the level of resources is combined with emotional or "drive" information that biases the direction of action either towards (approach) or away from (avoidance) a target object (Tops et al., 2010; Tops & de Jong, 2006). Thus, in reactive control, affect should be either positive or negative at any given moment. The continuous readout of available resources is needed only in low-predictable environments to allow for immediate action. In predictable environments, perceived levels of resources will be more tonically and stably derived from context models (see also Dambrun et al., 2012).

We will next discuss the model of Larsen, Cacioppo, and coworkers as it relates to our model and to the dynamic model of affect (Larsen, Hemenover, Norris, & Cacioppo, 2003). An important parameter of the Larsen et al. model is the severity of the stressor and the resulting coactivation of positive (approach) and negative (avoidance) emotional systems. For optimal health outcomes, their model posits that mild stressors should predominantly activate the positive emotional system, but severe stressors should coactivate the positive and negative emotional systems to enable active (problem-focused) coping (Folkman & Moskowitz, 2000; Larsen et al., 2003). Aspinwall and colleagues (2001) offer an explanation that seems in line with the model of Cacioppo and Larsen and with Thayer's theory. They argue that positive mood or experiences may serve as signals of resources that allow people to confront negative information. That is, the presence of a positive mood may be a signal that one's current resources are sufficient to deal with the task at hand. If resources are perceived to be inadequate, one may be motivated to preserve short-term well-being by denying or arguing against the information. However, if resources are perceived to be sufficient, one may be able to process such information veridically. In the case of optimism, the belief that future events are likely to be good may provide a chronically high estimate of one's affective resources and control capacities, resulting in the belief that one can overcome the costs of attention to negative information in most situations. We suggest that the explanation and model of Aspinwall and colleagues and of Cacioppo, Larsen, and colleagues reflect control that is guided by context models, which enables active coping in times of stress.

Emotion Regulation

Emotion self-regulation is an important aspect of resilience. It is also closely related to such approaches as the cultivation of positive affect, a kind of emotion regulation. Recent fMRI studies show that the ventral corticolimbic control network in the brain is involved in aspects of emotional (and physical) pain, emotion intensity, and emotional contagion (Craig, 2009). This network appears to be involved in a reactive and emotion-focused mode of regulating an intense experience of the emotional moment (e.g., by passively suppressing the emotional experience or expression). By contrast, the dorsal corticolimbic control network seems to be involved in goal-directed emotion self-regulation that serves feed-forward control and emotion dampening. This is achieved by regulating the activity in components of the ventral system such as the amygdala (for reviews see Ochsner & Gross, 2005; Phillips, Drevets, Rauch, & Lane, 2003a, 2003b).

Willpower and Cool Versus Hot Control

Research on stress often focuses on the amygdala. However, we think that, in humans, the cortical control areas such as IFG and anterior insula are important. A meta-analysis of anxiety activation in the brain by Etkin and Wager (2007) showed specifically that social anxiety was associated with right IFG activation. Several studies found that the right IFG is able to inhibit amygdala activity in response to negative stimuli or during emotion regulation. Notice that, although the right IFG is consistently active in social anxiety, it is also consistently implicated in neuroimaging studies of "cool" (i.e., relatively emotionally neutral) behavioral control. In this section, we make the argument that the right IFG is not part of the "cool" system (dorsal control can be better described as "cool"), but is part of the "hot" (i.e., emotionally reactive) ventral system (it is a control area of the "hot" system, e.g., keeping salient items in working memory or inhibiting responses, expression, or affect). The involvement of the right IFG in emotion inhibition and emotional (expressive) suppression in social anxiety may result from the association of social anxiety with social subordinance, which requires concealing and suppression of spontaneous emotional expressions.

An important promoter of resilience is willpower or the ability to control impulses. In predictive systems, context models can assist in directing behavior towards long- and short-term goals. In reactive systems, goals and motivational stimuli can be held active by redundant attentional and working memory processing that may actually lead to perseveration or obsessional behavior and rumination (Tops et al., 2010; Tucker et al., 1995). We adhere to the view that mediodorsal areas implement sustained episodic motivation control over behavioral episodes, guiding voluntary behavior based on the history of actions and outcomes (Tops & Boksem, 2012) and on context models. When action outcomes are unfavorable and/or context models suggest that it is better to stop the particular endeavor and do what "experience has taught is best for you," the endeavor will be abandoned in favor of flexible and adaptive switching to alternative endeavors or exploration. However, adapted to unpredictable environments, the ventrolateral prefrontal cortical controls of reactive systems may perseverate in order to exploit a potential opportunity (Tops et al., 2010). In this case, maintenance of drive and retrieval and/or maintenance of goals in working memory may keep goals active over time and, in the face of resistance, may help to implement effortful control of behavior in the service of the activated goals.

An influential dual-system framework has been proposed to aid in understanding the processes that enable or undermine self-control or "willpower," as exemplified in the delay of gratification paradigm (Metcalfe & Mischel, 1999). A cool, cognitive "know" system and a hot, emotional "go" system were postulated. The cool system is cognitive, emotionally neutral, contemplative, flexible, integrated, coherent, spatiotemporal, slow, episodic, and strategic. It is the seat of self-regulation and self-control. The hot system is the basis of emotionality, including fears as well as passions. It is impulsive and reflexive. Initially it is controlled by innate releasing stimuli (thus, literally under "stimulus control"). It is fundamental for emotional (classical) conditioning, and it undermines efforts at self-control. The balance between the hot and cool systems is purportedly determined by stress, developmental level, and the individual's self-regulatory dynamics (Metcalfe & Mischel, 1999; cf. Phillips et al., 2003a, 2003b).

The above description shows striking similarities with the present model, suggesting that the cool system can be mapped onto the dorsal control systems while the hot system can be mapped onto the ventral control systems. However, in earlier work (Tops & Boksem, 2011a; Tops et al, 2010), we noted the importance of distinguishing between dorsal and ventral prefrontal forms of cognitive control, and the frequent failure of most models and theories to do so. Here, we discuss a few examples of the tendency to ascribe "cool" to cortical control and "hot" to subcortical control, which we think ignores the fact that ventral cortical control is an intrinsic part of a fundamentally "hot" corticolimbic system.

The first example involves preschoolers who were classified on the delay-of-gratification task as less able to delay gratification and who later showed low self-control abilities in their 20s and 30s. These individuals were tested 40 years later on "hot" and "cool" versions of a *go/no-go* task. The low delayers performed more poorly than did high delayers when having to suppress a response to a happy face but not to a neutral or fearful face. In an imaging study (Casey et al., 2011), the right IFG/AI differentiated between *no-go* and *go* trials to a greater extent in high delayers, whereas the ventral striatum showed exaggerated activation in low delayers (Casey et al., 2011). Similarly, a review of the modern neuroimaging literature on brain structure, function, and connectivity in attention-deficit/hyperactivity disorder (ADHD) and conduct disorder showed that ADHD is characterized predominantly by abnormalities in IFG, striatal, and parietotemporal networks that mediate "cool" cognitive functions associated with the disorder. This was contrasted with dysfunction in "hot" networks including the amygdala in conduct disorder (Rubia, 2011). In a similar vein, Bechara (2005) suggested that addiction is the product of an imbalance between two separate, but interacting, neural systems that control decision making: an impulsive, amygdala system for signaling pain or pleasure of immediate prospects, and a reflective, prefrontal cortex system for signaling pain or pleasure of future prospects.

These examples show that the "coolness" of less reactive, context model-guided mediodorsal control is not typically discriminated from the "coolness" of the ventrolateral cognitive control elaborations of the reactive ("hot") systems themselves. Although dorsal context model-guidance systems may, at first glance, appear more cognitive compared to ventral reactive systems, each of them involves motivation and emotion and controls that continued to develop during evolution. The reactive systems produce a momentary, immediate sense of awareness, an experience of emotional stimuli as being close in time and space. However, the resulting intensity ("hotness") of incentives and drives is controlled by "willpower," the ventrolateral prefrontal controls that enable behavioral persistence in the face of distraction, temptation, and resistance (Tops & Boksem, 2010). However, the kinds of control, such as behavior or emotion inhibition and anxious rumination, may not be associated with *subjective* "cool" (Tops & Boksem, 2011b). By contrast, emotional experience in predictive control is less immediate and overwhelming (more "cool"); moreover, the successful context models that are shaped and used in predictive control will tend to include representations of positive experience and outcomes. To reiterate, this positive bias and the less intense emotions enable active coping through confronting both negative and positive affect.

The fact that self-regulation can involve the prefrontal controls of the "hot" ventral system may explain why self-control is often followed by subsequent breakdown of self-control ("rebound"). The ventral system type of self-control involves behavioral suppression that is similar to the freezing or tonic immobilization responses from which it is derived. During behavioral suppression, behavioral impulses that are triggered by pleasure or fear drives are inhibited. However, the motivational drive activation is not inhibited, such that, when opportunity arises and inhibition can be lifted, the drives can be enacted. Hypothetically, the prolonged activation of the drive during behavior suppression may increase the activation in ventral drive systems, which may make self-control more difficult subsequently, increasing the chance of behavioral rebound (Levine, 1997; Schmeichel, Harmon-Jones, & Harmon-Jones, 2010). Moreover, there may be a role for the continuous affective readout at the level of the right IFG/AI that we discussed in the earlier section on dorsal and ventral corticolimbic control pathways and the section on reactive affect and perceived resources. The continuous affective readout appears to keep track of the momentary level of resources the individual has in order to control his or her environment, be it social or physiological resources. This may be why negative affect, low social resources (social exclusion), and low physiological resources (blood glucose level) are associated with reduced self-control (DeWall, Baumeister, & Vohs, 2008; Gailliot & Baumeister, 2007). In our evolutionary history, when levels of resources were low, more opportunistic behavioral strategies may have been adaptive (Del Giudice, Ellis, & Shirtcliff, 2011).

Mindfulness Meditation

Mindfulness meditation is increasingly included in therapies and interventions to increase resilience. Comparable to the cultivation of certain kinds of positive affect and emotion regulation, mindfulness meditation may increase resilience by inducing a shift from ventral reactive control toward dorsal context model-guided control (Figure 2.2). The mindfulness approach promotes detached observation, which has the effect of increasing the individual's capacity to tolerate difficult emotions. The accompanying exposure transforms such emotions into innocuous states. Reactive tendencies to inhibit or otherwise to avoid sensations are prevented by increased capacity for tolerance and cool awareness. Awareness of context and of the whole range of choices available at any given moment is increased (Kent &

Davis, 2010). Mindfulness meditation is reflexive and goes with conscious access to the rich features of each experience and enhanced metacognition and self-regulation skills (Lutz, Slagter, Dunne, & Davidson, 2008). Mindfulness practice allegedly leads one to a clear but less emotionally reactive awareness of the autobiographical sense of identity that projects back into the past and forward into the future. In other words, it appears that the availability and guidance by context models are increased, thereby decreasing pure reactivity and increasing resilience.

In contrast to the open monitoring style of meditation, such as in mindfulness, the focused attention/concentrative style of meditation entails the capacities for monitoring the focus of attention and detecting distraction, disengaging attention from the source of distraction, and redirecting and engaging attention on the intended object (Lutz et al., 2008). We have proposed that these are typical IFG attentional functions (Tops & Boksem, 2011a). In both focused attention and open monitoring meditation there is focus on the moment, which may function to prevent ventral frontal involvement in elaboration, inhibition, and rumination. Although neuroimaging research on meditation is complicated by individual differences in strategies and nonlinear effects of proficiency (Lutz et al., 2008), there is support for involvement of ventral system areas in focused attention meditation and of dorsal system areas in open monitoring meditation. For example, in a study of practiced novices and expert Buddhist monks the most consistent effect was the deactivation of the precuneus or posterior cingulate cortex (dorsal system areas) during focused attention meditation in contrast to activation of these areas during open monitoring meditation (Manna et al., 2010). In another study, subjects were scanned while they adopted either a reflective, extended self-reference that links experiences across time in memory (which may involve the dorsal system) or a momentary experiential self-reference centered on the present moment (possibly ventral reactive). The experiential focus yielded reduced activity in dorsal system areas such as medial prefrontal cortex, posterior cingulate cortex and hippocampus, and increased engagement of ventral areas such as in the insula, secondary somatosensory cortex, IFG, and inferior parietal lobule (Farb et al., 2007). These results suggest a fundamental neural dissociation between two distinct forms of self-awareness consistent with the dorsal and ventral programs, which are generally integrated but can nevertheless vary within and between individuals in relative activation. Taken together, the evidence suggests that mindfulness meditation may increase resilience by inducing a shift from ventral reactive control towards dorsal context model-guided control.

CONCLUSION

We presented our model of the ventrolateral corticolimbic control pathways and the mediodorsal corticolimbic control pathways, and posit that they that are interacting but are also partly separable through their respective adaptations to environmental conditions that differ in the level of predictability (Tops et al., 2010). The reactive systems produce a momentary immediate sense of awareness, of sensing emotional stimuli as being close in time and space, and a tendency for emotion-focused coping. By contrast, when control is guided by context models, emotional experience is less immediate and overwhelming, has a wider temporal focus, has a sense of the past and the future, includes representations of positive experience and outcomes, and allows active coping through confronting both negative and positive affect.

The biobehavioral programs associated with ventral and dorsal control systems are evolved adaptive systems that are successful in certain environments and circumstances. Both systems represent talents and sources of resilience. The reactive ventral programs are sensitive and responsive to both negative and positive environmental influences. In the dorsal programs, the context models are dominant, are less responsive to environmental influences, and are experienced as less distressing. In the ventral programs, individuals become easily distressed in many environments. They may benefit from an increase in the ability to shift to dorsal control. We think that shifting from ventral towards dorsal control is a mechanism that is involved in various processes that increase resilience. We believe that awareness of the underlying brain mechanisms may help investigators to develop more targeted and effective interventions to assist individuals in becoming more resilient. Knowledge of these mechanisms may inform interventions as to which instruments and strategies to select and how to combine them for different persons and contexts, how to sustain gains, and how to best measure them.

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