CHAPTER 7

Neuroscience of Desire Regulation

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This excerpt well captures human beings' marked ability to monitor and control behavior in the service of aspirations and goals beneficial to health and well-being. For Cash, that goal was presumably the long-term commitment to June that caused him to "walk the line." For other individuals, it may be restricting food intake to maintain a slender figure, or faithfully attending support group meetings to remain sober and accountable to others who wish to do the same. Regardless of one's motivation to "walk the line," these lyrics show that the jukebox continues to deliver insights into human behavior (Pennebaker et al., 1979). They also raise questions about the situations in which these valued goals may fade from view and flee the mind: when an especially intense desire takes hold and pushes our thoughts and behavior to satisfy an immediate, gratifying impulse. Psychologists and neuroscientists have begun to uncover how and why we fail to "walk the line"—when we stagger away from it and experience self-control failure. To this end, researchers in the social brain sciences have identified neural mechanisms associated with how desire is represented and guides behavior on the one hand, as well as those that support the regulation of desire on the other.

In this chapter, we review these mechanisms in turn. Specifically, we will first consider how the brain processes reward and promotes reward-seeking behaviors, and then discuss how other brain systems can be recruited to curb desires and reduce the likelihood of acting upon impulses. Along the way, we will also incorporate theoretical models of desire and desire regulation that we believe the brain sciences are well equipped to validate. The chapter concludes with the most recent threads of neuroscience research that extend the literature and address key questions such as: What are the situations in which individuals are most likely to give in to desires (especially unfavorable and/or harmful ones)? Are brain systems amenable to training programs so that people can improve their capacity to effectively exert control over their desires? Although the neuroscience of desire and desire regulation is in its infancy, the field is beginning to address these issues head on, with increasing theoretical and methodological vigor.

Neural Mechanisms of Desire: How the Brain Processes Reward

Although the human experience of desire, in its various forms and intensities, is universal, the underlying mechanisms that give rise to it and its effects on behavior are not thoroughly understood. If anything, the emphasis to date has largely been on the human capacity to control desires, but recently there has been a galvanizing shift toward parsing out the psychological and neural components of desire (Hofmann & Van Dillen, 2012; see Part 1 in this volume). Without a doubt, there are many neural processes that work in concert to engender and shape our desires. For example, brain systems associated with memory formation (e.g., the hippocampus) form a functional loop with midbrain dopaminergic neurons when novel, rewarding stimuli are encoded and entered into long-term memory (Lisman & Grace, 2005). Of course, desiring a stimulus, whether it be a highly craved food item, sexual partner, or drug of abuse, necessitates retrieval of sensory and conceptual representations from memory. We do not downplay the importance of these other brain regions and networks, but for the purposes of this chapter we are going to focus on the mesolimbic dopamine pathway (MDP).

The MDP has been repeatedly shown in both human and animal work to be the critical brain system that undergirds reward processing (see also Kringlebach & Berridge, Chapter 6, this volume). Haber and Knutson (2010) review the functional neuroanatomy of the reward circuit in both humans and primates, identifying both cortical and subcortical regions in the MDP (Haber & Knutson, 2009). These regions include neurons in the ventral tegmental area (VTA), a midbrain structure that
sends dopaminergic projections to the nucleus accumbens, a cluster of neurons in the ventral striatum (VS). The VS has reciprocal connections with a set of cortical regions, including the ventromedial prefrontal cortex (VMPFC), orbitofrontal cortex (OFC), and anterior cingulate cortex (ACC) (see Figure 3 in Haber & Knutson, 2009).

How does the well-defined neural architecture of the MDP support the process of learning to desire rewarding things in the first place? And which computational and psychological mechanisms facilitate this process? In the past several decades there has been an impressive surge of research confronting these questions. Neuroscientists have implemented a wide array of tools to link brain function associated with reward representations in the MDP to motivated behaviors in which stimuli are desired and readily sought after. One line of work has discovered the initial, core computations the brain carries out when an organism is faced with a stimulus that acquires reward value. In a particularly impactful and seminal paper, Schultz, Dayan, and Montague (1997) offer a set of empirical findings that support a learning-based model of reward processing in which dopamine neurons in the VTA demonstrate firing patterns indicative of a prediction error signal (Schultz et al., 1997). This prediction error is characterized by a discrepancy between what an organism expects to happen in a given context and what actually happens. For example, when an animal receives an unexpected reward, there is a burst of activity in VTA dopamine neurons at the time of reward receipt. However, once a neutral cue (e.g., a tone) becomes a conditioned stimulus that reliably predicts the reward, those neurons show a temporal shift in their firing and will fire sooner, in response to the cue and no longer to the reward itself. The fundamental learning computation to predict reward from cues is essential for navigating daily life. For without such a learning process in place, the world we experience would be a “great blooming, buzzing confusion” (James, 1890/1950). Moreover, from an evolutionary perspective this mechanism has adaptive value; for instance, one might imagine its usefulness in helping our foraging ancestors discriminate between safe and toxic food sources, or learn physical cues signalling health and fertility in a potential mate.

Fast-forward many thousands of years to our modern, 21st-century existence in which our species is bombarded with more sensory cues—many in tantalizing high-definition—than we have ever encountered before (e.g., multiple streams of increasingly accessible digital media). How does the MDP, plus its attendant learning mechanism that can anticipate and discriminate rewards, fare in this cue onslaught and affect subsequent behavior? One line of thinking proposes that the reward component that the MDP primarily supports is incentive salience, a process by which reward-predicting stimuli (cues) acquire motivational value and by which reward-predicting approach behaviors toward the reward (Berridge & Robinson, 1998, 2003; Kringelbach & Berridge, 2009). Incentive salience is often characterized by “wanting,” a subconsciously motivated state that does not necessarily entail subjective desire but can still drive behavior (e.g., Winkielman, Berridge, & Wilbarger, 2005). Additional brain regions, such as the VMPFC and OFC, need to be recruited so that “wanting” breaks into conscious awareness and becomes explicit desire (Kringelbach & Berridge, 2009).

Whether desire arises from implicit “wanting” and leads to compulsive behavior in an automatic fashion, or from an explicit, goal-driven state (cf. Hofmann & Van Dillen, 2012), the MDP remains the key actor in how the brain engenders desire in response to rewarding stimuli. Accordingly, many researchers in the social brain sciences are focusing their investigations on reward processing in the MDP during functional magnetic resonance imaging (fMRI), a method that provides measures of task-evoked, regional blood-flow dynamics throughout the brain. This non-invasive “peeking” into the human brain as it represents and responds to rewarding stimuli presents a great opportunity for neuroscientists and psychologists to examine implicit processes that underlie desire (see also Sayette & Wilson, Chapter 5, this volume). This is especially true given that people are often unaware of the extent to which cues activate goals, desires, and behaviors (Bargh & Morsella, 2008), particularly compulsive behaviors (Stacy & Wiers, 2010). Cues can even activate implicit cognitive processes that predict substance use (Rooke, Hine, & Thorsteinsson, 2008; Tiffany, 1990).

Some of the earliest imaging work on reward processing observed striatal activity in response to monetary incentives, specifically cues that predict delivery of a cash reward (Knutson, Westdorp, Kaiser, & Hommer, 2000), suggesting that the striatum represents the value of a desired, rewarding stimulus. Other research groups have also found this value-based coding in the striatum by having participants complete a variety of monetary-based decision-making tasks (Delgado, Nystrom, Fissell, Noll, & Fiez, 2000; Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005). Given this MDP activity in response to monetary rewards and preferred choices, social brain scientists proceeded to ask how the brain encodes the value of appetitive cues, such as high caloric foods and drugs of abuse. To address this question, they turned to addiction research and adapted cue-reactivity paradigms, which have consistently produced strong effects across different drug domains (Carter & Tiffany, 1999; see also Sayette & Wilson, Chapter 5, this volume). The original cue-reactivity tasks exposed participants to sensory cues of a desired, sometimes forbidden substance (e.g., alcohol cues shown to alcoholics seeking treatment),

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2Although the dopaminergic prediction error mechanism described above occurs at the level of neurons, the blood-oxygenation-level-dependent signal acquired during fMRI serves as a reliable proxy for neuron-level firing patterns (Logothetis, Pauls, Augath, Trinath, & Oeltermann, 2001).
and then measured concomitant changes in self-reported craving and physiological responses.

Our lab has developed a cue-reactivity paradigm (Demos, Kelley, & Heatherton, 2011) that reliably elicits reward-related activity in the MDP (Demos, Heatherton, & Kelley, 2012). During an fMRI session, participants viewed images from multiple reward categories, namely the eating and sexual domains, and completed the task as described above. Findings supported a domain-specific account of rewarding processing in the MDP. Specifically, there was a positive relationship between food-cue-specific activity in the VS and subsequent weight gain 6 months following the scan. There was also a positive relationship between cue reactivity to erotic images and dyadic sexual desire scores. Critically, these effects followed a double dissociation: food cue activity was correlated only with weight gain and not sexual desire scores, while the reverse was true for erotic cue activity. A key implication of this study is that higher sensitivity of the MDP (indexed by greater VS activation) can drive future behaviors in which there is a strong desire to obtain a reward. Of note, participants in this study showed marked variability in both their food and sexual cue reactivity (see scatter plots in Figure 2 of Demos et al., 2012). This variability may reflect differential tuning of participants' reward processing in the MDP, with genetic factors and previous experience with a given reward or reward domain likely dictating the tuning.

This MDP tuning is even more pronounced in drug-using populations. Frequently, individuals who struggle with addiction engage in compulsive drug-seeking behaviors marked by implicit desire (“wanting”). Social brain scientists have sought to identify neural correlates of this distinctive MDP tuning in special populations. One initial study compared non-alcohol-dependent controls and alcohol-dependent participants exhibited higher VS activation in response to alcohol cues (Heinz et al., 2004). A similar effect was observed in smokers responding to appetitive smoking cues (David et al., 2005), and remarkably, cocaine users show VS activation to subliminally presented (33 milliseconds) cocaine cues (Chilcoat et al., 2008). These studies reveal that MDP tuning in these different populations affects reward processing of choice substances, providing a reliable brain-based marker of these groups’ impulsive “wanting” behaviors.

More recent fMRI studies have identified additional brain systems that may stimulate implicit desire and reward-seeking behaviors in these populations. For example, Wagner, Cin, Sargent, Kelley, and Heatherton (2011) showed smokers and nonsmokers naturalistic film clips, some of which depicted people smoking, and interrogated spontaneous activation patterns in response to smoking scenes in particular. They found that smokers recruited regions in the action observation network (Buccino et al., 2004; Hamilton & Grafton, 2006) more so than their non-smoking counterparts (Wagner et al., 2011). Although participants were in the scanner during the study and unable to perform any movements, the observed activity may represent precursor motor representations that increase the likelihood of engaging in the depicted smoking behavior. In this way, Wagner and colleagues’ findings highlights the role of the action observation network, corroborating William James’s original hypothesizing of the tight links between imagining actions and executing them (James, 1890). This line of work also illustrates the multifaceted nature of how desire is instantiated in the brain, for in addition to a core system (the MDP) that represents the salience and value of tempting stimuli, other sets of regions are called upon to prepare motor movements to obtain the coveted object (after all, Eve did have to reach for the apple). As we already alluded to before, collectively these brain mechanisms allowed for our evolutionary development and survival as a species. However, in our modern, cue-saturated lives, unhealthy eating choices abound, drugs (legal and illegal) become easy to abuse, and a quick hook-up with a stranger is only a few mouse clicks or smartphone taps away. Assuming we uphold goals of temperance and restraint (at least in some domains), we’re tasked with navigating through this thicket of temptation. Thankfully, there are neural mechanisms of desire regulation that offer us some hope as we “walk the line.” Let us turn to these steady mechanisms.

Neural Mechanisms of Desire Regulation

There has been no shortage of theorizing in psychology on how human beings regulate the push and pull of desire and impulses. Across many models, there is the common trope of desire mobilizing behavior to satisfy an impulse, and self-control as a restraining force to blunt desire and inhibit behavior (Baumeister & Heatherton, 1996; Hoch & Loewenstein, 1991; Hofmann, Frieze, & Strack, 2009; Kruglanski et al., 2012; Metcalfe & Mischel, 1999; see also Hofmann, Kotabe, Voils, & Baumeister, Chapter 3, this volume). In the past decade or so, social neuroscientists have
seized the opportunity to test these models by exploring neural correlates of desire regulation and self-control processes. Some of the earliest studies focused on people's capacity to actively control emotional responses to affective stimuli. These studies identified regions in the prefrontal cortex (PFC), specifically the dorsolateral and ventrolateral PFC, that people recruit when consciously changing their emotional reactivity (Ochsner et al., 2004; Ochsner, Bunge, Gross, & Gabrieli, 2002; Wagner, Davidson, Hughes, Lindquist, & Ochsner, 2008).

Inspired by this line of work, other social brain scientists wondered whether these same prefrontal systems might also be involved in the control of appetitive behaviors—when the target of regulation is not a negative emotion, but a desire for a rewarding stimulus. In a recent review (Heatherton & Wagner, 2011), we argue that prefrontal systems are recruited in a domain-general manner, but that the subcortical target of regulation will vary based on an individual's goals and regulatory context: the PFC will suppress activity in the amygdala in contexts that call for control of affective reactions, whereas it will inhibit activity in the MDP (e.g., the VS) to regulate appetitive behavior. In either case, activity in the PFC and subcortical systems interacts in the throes of intense emotion or temptation will dictate self-control outcomes (see Figure 7.1; Heatherton & Wagner, 2011). Our balance model predicts that self-control failure is especially likely whenever activity in subcortical systems becomes unchecked and unregulated by the PFC.

The extent to which prefrontal systems are utilized in the service of a regulatory goal is a critical question for studying desire control. In a short time, the tools of brain imaging have made promising inroads. Hare and colleagues (2009) conducted one of the first studies to tackle this question. Dieters completed a food decision-making task during an fMRI scan, while brain activity was measured as the dieters made their choices, one of which was honored at the end of the study. The main finding was that the dorsolateral PFC modulates activity in the VMPC, a region in the MDP hypothesized to encode the value of appetitive food stimuli. One example of this modulation effect was a negative relationship between activity in the dorsolateral PFC and VMPC (see Figure 3C in Hare et al., 2009) in response to appealing food items during trials in which participants exerted self-control (i.e., opted not to eat the depicted food).

Another important region in the PFC that neuroscientists have focused on in desire regulation research is the inferior frontotemporal cortex (IFG/VLPFC). Activity in this region was observed in early cognitive neuroscience work as a robust correlate of stopping prepotent motor responses in the context of response inhibition tasks (Aron, Robbins, & Poldrack, 2004). In a more recent review (Aron, Robbins, & Poldrack, 2014), the authors highlight the role of IFG/VLPFC in impulse control disorders, citing work showing that impaired IFG/VLPFC functioning characterized illicit drug use in a large sample of addicts (Whelan et al., 2012). This implicates IFG/VLPFC in the successful regulation of desires for rewarding stimuli. Indeed, Kober and colleagues (2010) found that smokers recruited a set of regions in the PFC (including IFG/VLPFC; see their Table S1) when employing cognitive strategies aimed at reducing their craving for cigarettes. They also found a statistical relationship between PFC and VS (assessed via mediation analysis) that supported successful control of craving (Kober et al., 2010).

With this mounting evidence, social neuroscientists have set out to establish ecological validity of the IFG/VLPFC's regulatory functions. To do so, they have taken the "brain-as-predictor" approach (Berkman & Falk, 2013) linking activity in the IFG/VLPFC with daily self-control dilemmas requiring successful desire regulation. One of the first demonstrations of this link was in the smoking domain (Berkman, Falk, & Lieberman, 2011). Heavy cigarette smokers in smoking-cessation programs completed a go/no-go response inhibition task (Casey et al., 1997) while undergoing an fMRI scan and then reported on their daily smoking behaviors for several weeks after the scanning session. Berkman and others found that those smokers who showed higher IFG/VLPFC activity during inhibitory (no-go) trials smoked less in their daily lives, even in the

3Although rewarding and emotional stimuli are primarily processed in subcortical systems, there are cortical regions that also encode affective and appetitive aspects of stimuli, so "subcortical target" is a bit of a misnomer. Since our 2011 review, cited above, subsequent work has identified regulatory mechanisms between PFC systems and cortical sites associated with evaluative processing, such as the OFC (Wagner and colleagues, 2009).
face of high levels of prior craving (see Figure 4 in Berkman et al., 2011). Another important finding was that those smokers with greater amygdala activation during inhibitory trials (likely an index of the strength of the prepotent response to be inhibited) were more likely to succumb to strong desires to smoke. The findings in this study support our balance model of self-regulation (Heatherton & Wagner, 2011), and demonstrate that IFG/VLPFC activity is not merely a correlate of lab-based performance on a VLPFC task, but rather that this activity seems to reflect an individual's self-control capacity in the face of strong everyday desires.

In a more recent study we found a similar effect with predicting real-world eating behaviors (Lopez, Hofmann, Wagner, Kelley, & Heatherton, 2014). Participants first completed an fMRI session, during which they completed the cue-reactivity paradigm described above and a go/no-go task, and then reported on their daily eating behaviors 1 week after the scan. Higher cue reactivity in the VS predicted stronger food desires, greater likelihood of giving in to those desires, and more food eaten, while greater IFG/VLPFC activity associated with response inhibition in the go/no-go task facilitated successful resistance to desires (i.e., reduced likelihood of giving in to a desire; see Figure 1 in Lopez et al., 2014).

We have only scratched the surface of understanding how our prefrontal systems serve as our better angels in regulating desires and guiding our behaviors. And despite the extraordinary opportunity modern brain imaging affords to view the live workings of the human brain, new questions outpace any answers. This is especially true of questions pertaining to higher-order cognitive processes that entailing flexible control of impulses and behaviors across (or even within) individuals. We now consider the most recent studies and new theorizing in the neuroscience of desire regulation that we hope will push the frontier of knowledge further.

### Latest Research Developments in the Neuroscience of Desire Regulation

Given that neuroscience has localized both desire-generating brain systems (i.e., the MDP) and desire-regulating ones (e.g., the IFG/VLPFC), researchers can now finely probe psychological processes and interrogate accompanying patterns of activity in these systems. The two methodological approaches that follow from this idea are: (1) manipulating processes of interest and measuring subsequent neural activity, and (2) measuring naturally occurring variability in those processes, and noting any associated changes in neural activity. In short, the first is the traditional experimental approach that contextually constrains which neural mechanisms may be engaged and to what extent, while the second is an individual differences approach. With regard to the first approach, we would expect brain mechanisms of desire to be engaged and/or exaggerated in specific contexts, such as those in which people's self-control capacity is somehow compromised, allowing reward-related activity in the MDP to have free reign.

This scenario hits close to home in the chronic dieting population, a group that is prone to experience self-control failure in the eating domain despite repeated efforts to curb intake (Heatherton, Polivy, & Herman, 1991; Herman & Mack, 1975; see also Roefs, Houben, & Werthmann, Chapter 16, this volume). Under neutral conditions, dieters are generally successful in restraining their eating, and in fact show little reward activity in the VS (cf. Figure 3 in Demos et al., 2011). However, situational triggers such as negative distress (e.g., Heatherton et al., 1991; Heatherton, Stipe, & Wittenberg, 1998), dietary violations (Heatherton & Baumesiter, 1991), and self-regulatory depletion (Vohs & Heatherton, 2000) can throw the rider off the horse, sending the horse down the road of failure.

These triggers were originally identified behaviorally and often led to increased levels of desire and consumption. But it remains unclear how the brain gives rise to such effects. A line of work conducted in our lab has studied all three triggers while dieters underwent fMRI scans and completed the cue-reactivity paradigm, as described above. Consistent patterns of amplified reward activity in the MDP (VS and/or OFC) in response to food cues when dieters were distressed (Wagner, Boswell, Kelley, & Heatherton, 2012), when their diets were broken by a milkshake preload (Demos et al., 2011), and when their self-regulatory capacity was diminished (Wagner et al., 2013).

Another sphere of research in our lab, corresponding to the individual differences approach, has investigated the link between inter-subject variability in reward processing and self-control and real-world self-control outcomes. Our study on the neural predictors of giving in to daily temptations to eat (Lopez et al., 2014) and the Demos et al. (2012) study predicting long-term weight gain suggest that sensitivity of the brain's reward systems (i.e., the VS) to food cues predisposes people to succumb to desires to eat on a daily basis, which, over time, may translate to patterns of overeating and weight gain. There is much to be explored with the individual differences approach. One new dimension of this uncharted territory is the self-relevance of tempting stimuli and how these stimuli are represented in the brain, giving rise to subjective desire. One recent study by Giuliani, Mann, Tomiyama, and Berkman (2014) measured brain activity as participants regulated their desires for personally craved stimuli, identifying a set of prefrontal regions specific to regulation of those stimuli (versus noncraved stimuli), including the DLPFC and IFG/VLPFC.

Another rapidly developing research platform seeks to determine whether brain systems that underlie regulation of desire are amenable to training, and if so which systems should be the targets of training programs. With our balance model in view, one can make two reasonable
suggestions: (1) given that self-control failure is more likely when desires and impulses, mediated by reward processing systems, dominate and govern behavior, these systems should be the targets of training regimens with the goal of dampening responsivity to rewarding stimuli; (2) conversely, since activity in prefrontal systems seems to represent one's capacity to regulate and override desires, these systems should also be the focus of training programs. With regards to the first approach, the empirical support is scarce at best, but there are some hints that it may be tractable. A new study by Gross and associates (2014) provides compelling evidence that higher-order value computations in the medial PFC may be carried out in a common value space, regardless of the object or domain whose value is computed (Gross et al., 2014). As the authors argue, this raises the possibility that the value of different stimuli and behaviors is exchangeable. If that is the case, then a self-control training program could target this region of PFC, which has reciprocal connections with subcortical reward systems in the MDP, as we showed earlier. Such a program could decrease the value of previously desired stimuli (a savory food item) and increase the value of a self-relevant goal to diet and exercise regularly. A demonstration of medial PFC modulation by Schonberg and colleagues (2014) offers the possibility that evaluative processing may indeed be plastic and changed via relatively simple, cue-based interventions.

The second suggestion has increasing support from neuroimaging studies. In one study, participants showed changes in recruitment of prefrontal regions following inhibitory control training, with some regions' activity increasing in the post- versus pretraining comparison and others decreasing their activity (Berkman, Kahn, & Merchant, 2014). This pattern of regions increasing and decreasing activity may represent different aspects that promote efficiency in the context of response inhibition (i.e., proactive versus reactive control). Follow-up studies should consider how these aspects might translate into effective self-control in daily life, and the extent to which changes in prefrontal systems have domain-general versus domain-specific effects (e.g., whether motor control training via a go/no-go task can positively impact self-control outcomes in the eating domain). Another recent study showed decreased DLPFC recruitment following a 1-hour training session that caused participants to alter their food preferences (Schonberg, Bakkour, Hover, Mumford, & Poldrack, 2013). This suggests that although there is strong evidence that prefrontal systems support self-control, inhibitory processes carried out by these systems might become automatized (indexed by less activity) and lead to successful desire regulation. To conclude, the jury is still out with regard to which brain systems should be the targets of training procedures, and neuroscientists will need to consider how the magnitude and direction of changes in PFC activation patterns meaningfully track with behavioral outcomes.

In this chapter, we teased apart neural mechanisms that generate desire and prompt us to pursue tempting stimuli. We saw that the core reward-processing system is the MDP, with both subcortical (VS) and cortical (VMPFC, OFC) regions as key players. We next reviewed prefrontal systems that interact with the MDP to keep desire in check and control behavior in a domain-general fashion. Lastly, we surveyed the interesting but wild terrain of the latest desire regulation research. Currently, there are more questions than answers, but the neuroscience of desire regulation is well positioned to address those questions. Social brain scientists are beginning to leverage more sophisticated brain imaging modalities, including measures of structural and functional connectivity, as well as multivariate techniques to analyze patterns of neural activity within and across regions. We are hopeful that the next several decades will be an exciting and quickly evolving period for the field, as our understanding of the brain's role in generating and controlling desires will come into greater and greater focus.

REFERENCES


Individual Differences in Desire and Approach Motivation

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In this chapter, we approach the empirical study of individual differences in desire from the perspective of approach motivation. We define approach motivation as simply the urge to go toward (Harmon-Jones, Harmon-Jones, & Price, 2013), and we believe many variations of desire fit this definition. By our definition, which is based on decades of experimental, clinical, and neurological research, approach motivation (desire) does not require a stimulus or goal; it is not necessarily toward a positive outcome; and it is not necessarily experienced as a positive state. Evidence presented below will clarify why this is so.

By defining desire as fundamentally an approach-motivated state, we seek to distinguish the term from the more commonly used discrete emotion of desire, which is usually assumed to be an affective state positive in valence and associated with positive outcomes (e.g., desire for a delicious dessert or attractive individual). We believe this subjectively positive affective state is only one way through which desire can manifest. As the chapter unfolds, we hope it becomes clear why we prefer an empirically based definition of approach motivation, and how this definition relates to a broader understanding of desire.

In this chapter, we review research on individual differences in approach motivation and how they relate to electrophysiological indices and influence cognitive and emotive responses. We focus primarily on the most widely used measure of individual differences in approach motivation, the behavioral activation system (BAS) sensitivity scale developed by Carver and White (1994). This questionnaire was based on the original version of Gray's (1990) reinforcement sensitivity theory. Carver...